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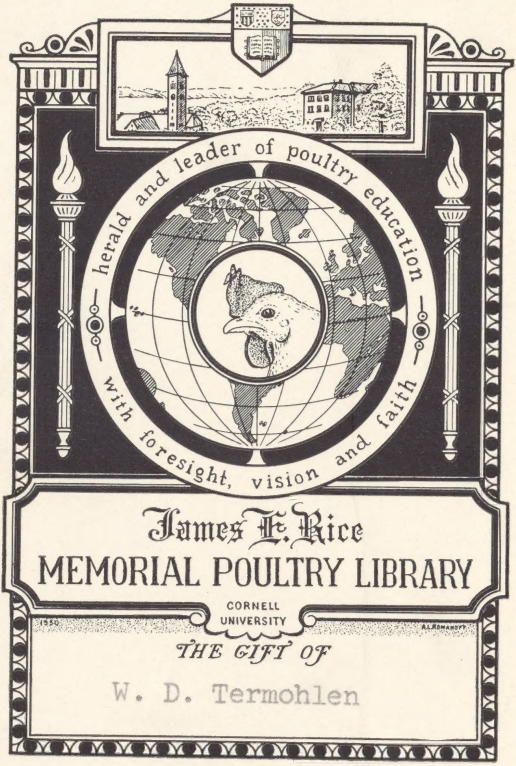

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MOULTING. By Lewis Wright (See page 82).

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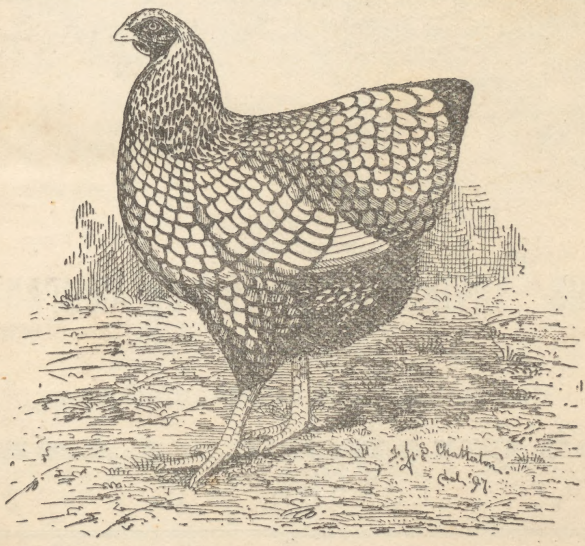

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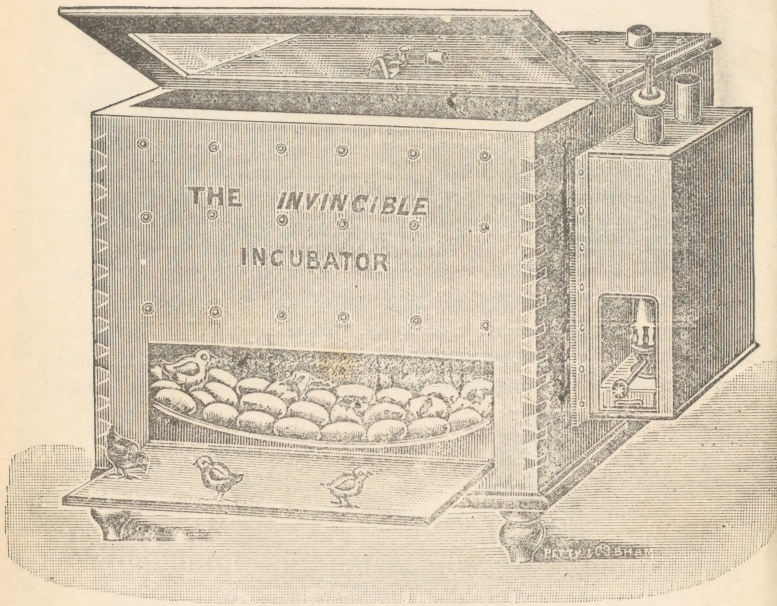

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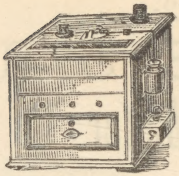
THE Peripage  Incubator.

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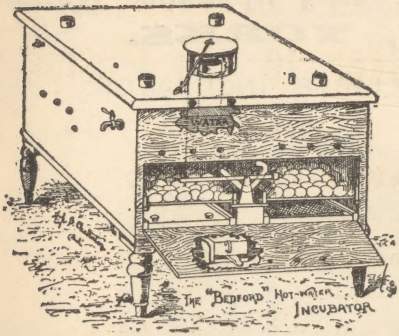

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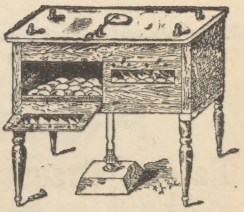

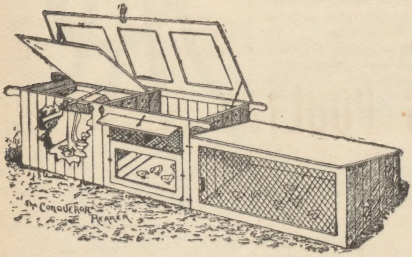

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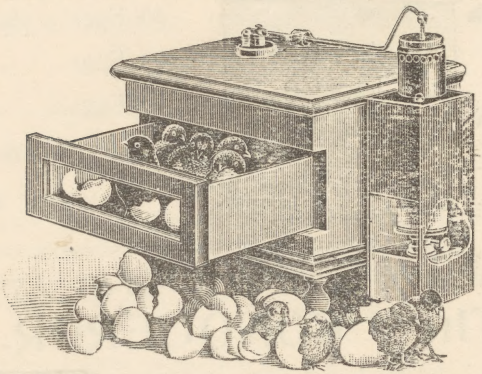

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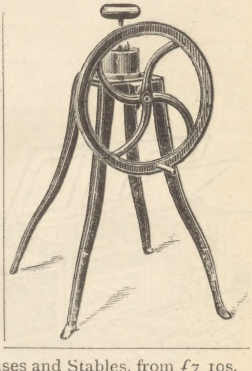

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AND ITS LAWS

BY

J. H. SUTCLIFFE

(Author of "Incubators and their Management," "Duck Farming," "Profitable Poultry Farming," "Poultry Keeper's Account Book," etc).

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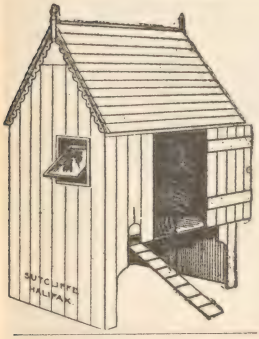

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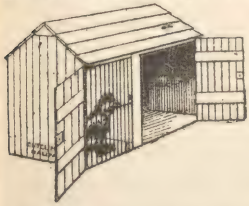

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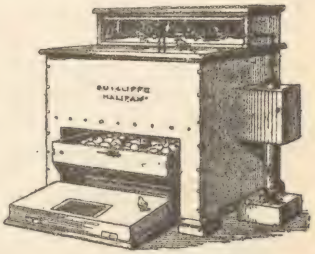

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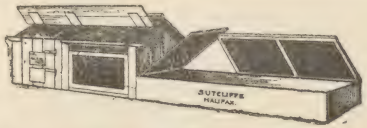

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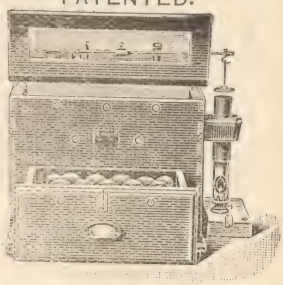

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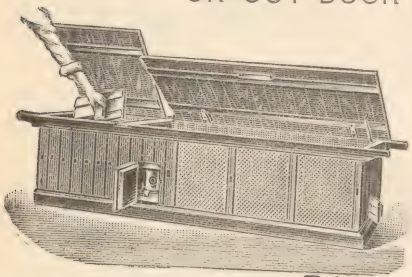

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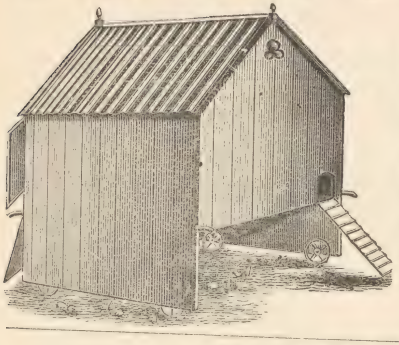
PREFACE.

That it is customary to write a preface is the Author's excuse for writing one to this book. In its pages an attempt has been made to treat, as exhaustively as space will permit, the subject of incubation, to explain the physical laws bearing thereon, to discuss from a scientific standpoint the fundamental principles and essential conditions of Nature's method, to see wherein, and to what extent, those principles are applicable to the artificial method, and to endeavour to show the various influences that may affect, either beneficially or deleteriously, the embryonic development of the chick in its different stages. Although the subject of artificial incubation is not a new one, it is only in recent years that it has come into prominence, and there are, as yet, many phenomena unexplained, much conjecture concerning the causes of success or failure, and generally speaking, comparatively little definitely ascertained truth as the result of systematic experiment, that our knowledge on the subject is far from being a perfected science. If this book throws any light upon the subject, or assists the amateur incubator operator to secure better results, or in any way hastens the day when the artificial method will, to the advantage of all concerned, supercede the natural one, its mission will have been fulfilled.

J. H. S.

FOWL HOUSE



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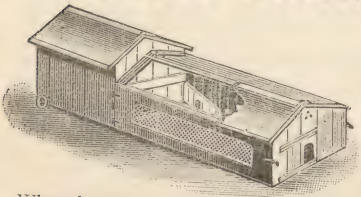

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Artificial Incubation and its Laws.

CHAPTER I.

INTRODUCTION.

ARTIFICIAL Incubation has been practised by the Egyptians from the remotest times. Far back in the dark ages, the Egyptians built houses, or "mahmals" (so named on account of their life-giving properties), in which the eggs were placed, and which were heated by furnaces, and kept at the desired temperature by vigilant attention. At the present day these house-incubators are conducted on lines similar to those of a thousand years ago. The attending to these incubatories forms a regular industry during about three months of the year, the secrets of which business are jealously guarded, and handed down from father to son. Our circumstances, however, are such that we have been able to copy nothing from the Egyptians to assist us in the construction of an incubator to be of service in a variable climate like our own, the modern machine having been developed quite independently of any aid from the ancient methods just referred to.

CHAPTER II.

ADVANTAGES OF ARTIFICIAL INCUBATION.

The great advantage of an incubator is that its inclination "to sit" has not to be consulted, it being always ready for that duty at any season of the year. Chicks may thus be hatched, and with suitable appliances, reared at any time.

To breeders for the table, who would have fat chickens when the highest prices are obtainable, that is before the later, naturally hatched chickens become plentiful, incubators are a necessity.

To ensure a plentiful supply of eggs in Autumn and Winter the chicks should be hatched in March and April. Sitting hens are not, as a rule, sufficiently plentiful in February and March to enable the poultryman to get as many pullets as desirable during the former two months.

Where artificial incubation is used, non-sitting varieties of fowls may be kept with more profit, as hens which have no part of their time occupied with maternal duties, lay more eggs. Far more eggs can be hatched with an incubator in a given time than with hens, and much less attention is needed; in

fact, a maximum of results can be obtained with a minimum of trouble.

With incubators, no eggs need be lost by breakage, or by exposure and chilling, and no chicks are crushed to death. Incubator-hatched chicks start life free from the insect pests which sap the life blood of many of those hatched under hens.

They are more easily and cheaply reared in foster-mothers. The chicks, and especially the weaker ones, often suffer by being led into damp grass, or too long distances by their mother, who regulates her pace, to a great extent, by the stronger chicks. On the contrary, foster-mothers provide snug and warm quarters, always ready for their work, which is not the case with a hen, it being no uncommon thing to hear some chicks chirping to be brooded, while others of the same brood have no such desire. Artificially-reared chicks are also more independent, less timid, and look out better for themselves. They can also be fed more regularly, more evenly, and more economically, as there is no mother to greedily devour the tit-bits and more expensive food on which chicks are usually fed. Artificially-reared chicks are also less liable to disease, accident, and the raids of vermin.

CHAPTER III.

NATURAL INCUBATION.

The more nearly the artificial method of incubation can copy the natural one, the more successful will be the results. We will, therefore, observe first the conditions of the natural process, and from them learn, as far as possible, the principles that must guide us in the use of the artificial method.

When a hen becomes broody, the arteries and veins under her body become more highly developed, and cover the abdomen with a rich network of warm blood-vessels, which, being pressed against the eggs, keep the latter at a temperature approximating that of the fowl's blood.

During the 20 or 21 days that a hen sits on her eggs, she frequently turns them in the nest, probably simply re-arranging them to her own comfort, but, at the same time, fulfilling an absolutely necessary condition to the successful development of the embryo. In settling down to her eggs, after being off for a time, the hen generally performs the operation with a wriggling motion, and in so doing, she separates the eggs slightly, and partly surrounds them with her downy feathers, a small portion only of each egg coming in contact with her body.

It will also be noticed that, as incubation advances, the small end of each egg has a tendency to turn towards the middle of the nest, and the broad ends to become slightly elevated, owing, mainly, to the nest becoming deeper, and to the enlarging air space in the broad end causing the narrow end to be the heavier.

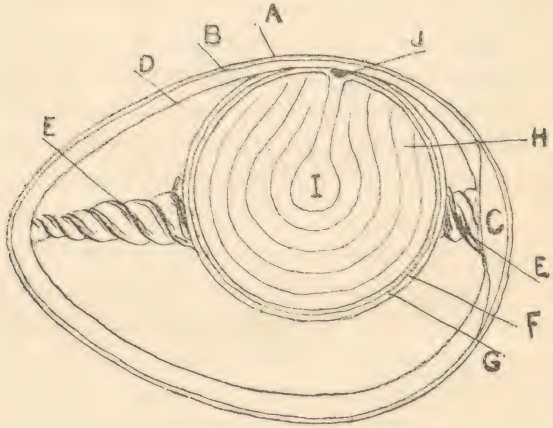
The number of times a good sitter will leave her nest, and the length of time she will stay away, depends, in a large measure, upon the weather. In warm weather, these journeyings will be of more frequent occurrence and of longer duration than in cold weather. She may sometimes be noticed, when the weather is hot, to rise in the nest, and shake out her feathers, as if to cool herself and her eggs.

CHAPTER IV.

STRUCTURE OF THE EGG.

A general knowledge of the structure of the egg, and the developement of the germ are essential to the proper understanding of the science of artificial incubation.

The shell consists of two layers of carbonate of lime the inner layer being thicker than the outer one. The particles of these layers are arranged in such a manner as to give the greatest strength to withstand pressure from the outside. Innumerable minute holes, or pores, penetrate the shell to permit of the free interchange of gases, and to allow moisture to escape during incubation. By the action of this vapour, saturated as it is with carbonic acid gas, and the



SECTION OF UNINCUBATED FOWL'S EGG.

A, the shell; **B**, the double membrane attached to the shell, and separating at the large end to form the air space, **C**; **D** shows the boundary of the inner portion of albumen; **E, E**, the chalazæ, which holds the yolk suspended in the egg; **F**, the membrane surrounding the yolk; **G**, layer of fluid albumen (in which the yolk rotates) inside the layer of denser albumen which merges into the chalazæ; **H**, the yolk, consisting of several layers; **I**, the utricle, central part of yolk of less density; **J**, the germ.

constant heat of the hen's body, the shell, by the time of hatching, loses its strength of texture, the particles become blended and confused, and the shell brittle, thus rendering the exit of the chick easier.

Lining the shell, and enclosing the white of the egg, are two delicate porous membranes. The outer one thicker than the inner. These two membranes remain in contact, except at the broad end, where they separate, and form the air space, or air chamber, so small in a new-laid egg as to be almost invisible, but which gradually increases in size as the contents of the egg condense, whether incubated or not, by the evaporation of the water of the white, of which 84 per cent. of the latter consists.

The degree of freshness of an unincubated egg can, therefore, to a limited extent, be tested by the size of the air vesicle, the latter in a very stale egg, or in one ready for hatching, occupying from one-sixth to one-fifth the space.

The white of the egg consists of alternate layers of denser and more fluid albumen (the composition of the white being about as follows:—Water 84 per cent., dry albumen $12\frac{1}{2}$, mineral matter 1, and sugar, etc. $2\frac{1}{2}$), gradually increasing in density towards the yolk. In a hard-boiled egg these layers can often be peeled off

singly. This albumen is highly nutritious, and as it is consumed in building up the tissues of the chick (the yolk suffering little diminution till hatching time), its absorption gives the latter the necessary additional room. Being a bad conductor of heat, it preserves the germ against sudden changes of temperature, and, by its elasticity, protects the yolk against injury from violent concussion.

Extending from each end of the egg to the yolk, is a kind of coil of twisted denser albumen, the function of which is to keep the yolk more steadily suspended in the centre of the egg, and so counteract the ill effects of the concussion as mentioned above. These chalazæ (as the twisted coils of albumen are termed) terminate at one end near the outer layer of the white, and at the other end they merge into the denser layer of albumen, next the more fluid one, which adjoins the yolk.

Inside the white is the yolk, the most nutritious part of the egg, composed about as follows :—Water 52 per cent., oil and fat 45, albumenoids 1, colouring matter 1, mineral matter 1. It is enclosed in a fine, transparent, non-porous membrane to prevent its admixture with the white. This yolk dimishes very little in size till within about 24 hours before the chick leaves the shell, when it begins to be absorbed

through the navel into the abdomen, this provision of nature thus supplying the chick with highly nourishing food during the first hours of its life. The yolk, like the white, is arranged in layers, with a small central mass of less density, called the utricle, from which a passage runs to the side of the yolk where the germ is located.

Floating on the upper surface of the yolk, and just under the membrane enclosing it, a dark semi-circular speck, about one-eighth of an inch in diameter, may sometimes be seen when an egg is broken into a saucer. This is the germ, or embryo of the future chick, which, owing to an admirable provision of nature, always floats on the top of the yolk, and is thus kept as near as possible to the body of the sitter. This is effected by the yolk being denser and therefore heavier on the side opposite the germ. In whatever position the egg may be turned, provided there is no check to the rotation of the yolk, such as the germ adhering to the shell, the centre of gravity of of the yolk being always on the opposite side from the germ, the latter comes to the top. As the yolk is of less density than the white, it has, also, a tendency to rise to the top of the egg, while the comparatively heavy albumen of the chalazæ, being attached to each side of the yolk, in a line with the long axis of the

egg, tends to relieve, or moderate the pressure of the upper portion of the yolk, on which the germ rests, against the shell.

CHAPTER V.

DEVELOPMENT OF THE EMBRYO.

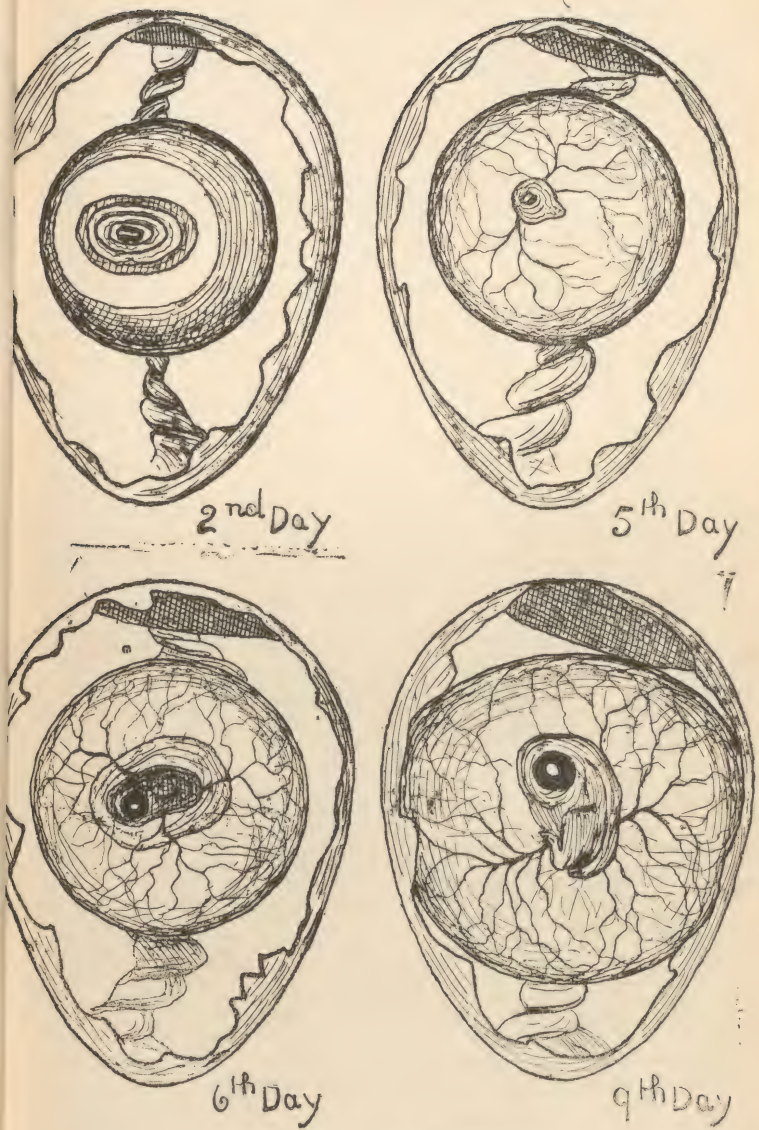
When the yolk is expelled from the yolk-sac into the oviduct, the germ disc is impregnated by the male. In its passage along the oviduct the yolk becomes, firstly, coated with the albumen, or "white," secreted from the mucous membrane of the passage; secondly, the white is encased in membrane, and lastly with the shell. After being laid, the vitalized egg lies dormant till subjected to the proper degree of heat, when the outer edges of the germ commence to enlarge uniformly on all sides, till the yolk is completely enclosed in a kind of germ-membrane. From the inner part of the germ, minute blood-vessels originate, which, like the germ-membrane alluded to, but slower in their growth, spread out evenly, and also surround the yolk.

By the end of the first day of incubation, the germ,

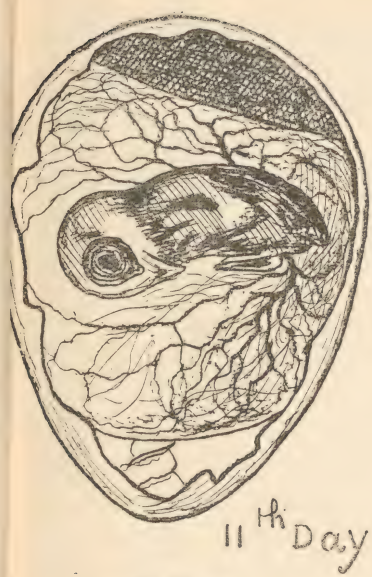
spot has considerably enlarged, the minute blood-vessels are just distinguishable from the growing germ-membrane, and out of the very centre of the embryo, faint traces of the head of the chick may be discerned. On the second day, the outline of the tail as well as the head can be seen, also the first appearance of the heart, which towards the end of this day begins to pulsate, the blood at first being almost colourless, and its flow, in the already-formed blood-vessels, being apparently as yet independent of the pulsations of the heart.

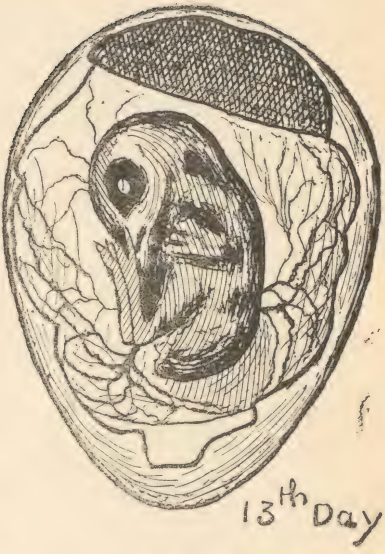
During the third day, the blood-vessels become connected, and form a small, but complete circulatory system, which, as the white becomes absorbed, is brought close to the membrane lining the shell, and to which it becomes attached. The shell, being porous, admits the air necessary to aerate the blood, and supplies also the lime for the bones of the chick. By the fourth day, the curved position of the embryo, with head and tail meeting, may be seen. About the seventh day, the chick begins to open out, signs of the neck appear, and the body, until now very small in proportion to the head, begins to grow relatively quicker. The first appearance of the small horny scale at the end of the beak may be seen on the eighth day. By the ninth and tenth days, rudimentary

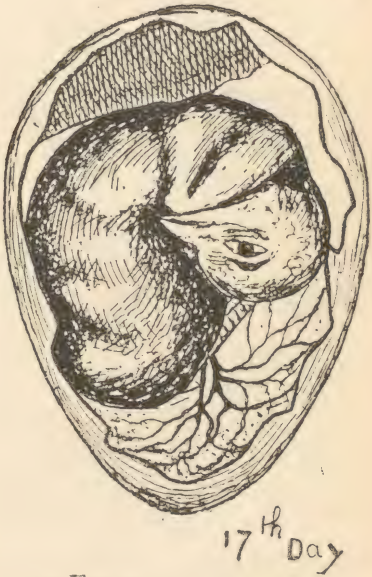
feathers, encased in minute tubes or sacs, are visible. About the thirteenth day, the skeleton of cartilage is about complete. The chick, until fully developed, is encased in a membrane ; this, about the nineteenth day, is broken by the beak of the chick, which then begins to use its lungs by breathing the air in the now much-enlarged air-chamber. At this stage the chick occupies its smallest space in the egg, the air-vesicle alluded to occupying about one-fifth or one-sixth of the interior. When this vesicle is broken, the chick commences its struggles for liberty, and by its muscular efforts, gradually works itself up till it fills the whole space. This gives it greater freedom, and enables it more easily to extricate itself. The peculiar so-called 'tapping' sounds heard at this time, and sometimes supposed to be caused by the tapping of the beak against the shell in the chick's endeavours to break its way out, are produced by the incipient respiration of the chick, being simply the sounds caused by puffs of air exhaled from the lungs, which are just beginning to be used. Other sounds may also be heard on putting the egg to the ear, namely, the struggling efforts of the chick to gain more room, and the strokes of the beak on the shell, which occur at unequal intervals dependent upon the vigour of the chick.



DEVELOPMENT OF EMBRYO.







DEVELOPMENT OF EMRBYO.

DEVELOPMEFT OF EMBRYO.

The following more detailed description of the stages of the development of the embryo, given by a French scientist, may also be added with advantage. To facilitate his experiments he removed small portions of the shell about the size of the diameter of a pea on either side of the egg, without injuring the lining membrane, and carefully fitted thin pieces of glass to the openings.

"I placed the egg with the glass bull's-eyes in an incubator run by clockwork, and revolving once each hour, so that I had the pleasure of looking through, and watching the changes upon the inside at the end of each hour. No changes were noticeable until about the end of the 12th hour, when some of the lineaments of the head and body of the chick made their appearance. The heart appeared to beat at the end of the 24th hour, and in 48 hours two vessels of blood were distinguished, the pulsations being quite visible. At the 50th hour, an auricle of the heart appeared, much resembling a lace or noose folded down upon itself. At the end of 72 hours, we distinguished wings and two bubbles for the brain, one for the bill, and two others for the forepart and hindpart of the head. The liver appeared at the end of the 5th day. At the end of 131 hours the first voluntary motion was observed; at the end of 148

hours the lungs and stomach had become visible, and four hours later the intestines, the loins, and the upper mandible could be distinguished. The slimy matter of the brain began to take form and become more compact at the beginning of the 7th day. At the 190th hour the bill first opened and the flesh began to appear on the breast. At the 194th hour the sternum appeared. At the 210th hour, the ribs had begun to put out from the back; the bill was quite visible, as was also the gall bladder. At the beginning of the 235th hour the bill had become green, and it was evident that the chick could have moved had it been taken from the shell. Four hours more and the feathers had commenced to shoot out, and the skull to become gristly. At the 264th hour, the eyes appeared, and, two hours later, the ribs were perfect. At the 331st hour, the spleen drew up to the stomach and the lungs to the chest. When the incubator had turned the eggs 335 times, the bill was frequently opening and closing as if the chick was gasping for breath. When 351 hours had elapsed, we heard the first cry of the little imprisoned biped, From that time forward he grew rapidly, and came out a full-fledged chick at the proper time."

CHAPTER VI.

HEAT—HOW FORMED.

Animal heat is formed by the chemical union of oxygen and carbon. The oxygen of the air inhaled into the lungs is carried by the corpuscles of the blood into the organs of the body, where, by uniting with the carbon of the waste or decayed tissues, carbonic acid is formed. The latter is conveyed by the same channels back to the lungs to be exhaled, and a fresh supply of oxygen is received.

Wherever this chemical union takes place, heat is generated in proportion to the activity of the chemical action, and the quantity of the neccessary elements present. In an egg all the elements necessary for the development of the chick, except oxygen, are already present in sufficient quantities in the white and yolk. Oxygen enters through the pores of the shell, and from the very first day oxidation takes place, although in the early stages of incubation, probably very little oxygen is used, as the chemical action set up by the heat of the hen's body is at first directed mainly to the building up of the structures of the embryo, the breaking down or heat-generating process of burning not being perceptible.

CHAPTER VII.

THE HEATING OF THE EGGS BY THE HEN.

In natural incubation heat is applied to the eggs by actual contact with the incubating body, although in the earlier stages, the down and feathers may prevent, to a considerable extent, this direct contact. The bodily heat of the sitting hen is greatest at the commencement of incubation, and as its heat decreases, the feathers and down under its abdomen disappear, and the eggs are brought closer to the source of heat, so that, notwithstanding this diminution of warmth in the incubating body, the difference in the amount of heat imparted to the eggs between the earlier and the later stages is not so great as would otherwise be the case. Moreover, although the bodily temperature of the sitter diminishes from two to four degrees as incubation progresses, the development of the rich network of blood-vessels in the abdomen increases, more and more blood coming to the under surface of the fowl's body, and in contact with the eggs.

In addition to direct contact, warmth is applied, by the diffusion of heat downwards by the feathers, which fill the spaces between the eggs and all round the outsides of the nest. The cool, fresh air comes in under the eggs and close to the bottom of the nest,

gradually ascends to the heat-generating body, and becomes heated, but instead passing out on the tops of the eggs only, its exit laterally is resisted and retarded by the downy fluff and feathers, which conduct and diffuse the heat downwards as well as outwards, and hold suspended among them a large volume of warm air, any rapid movement of which being impossible. Moreover, the outgoing warm air meets, and parts with most of its heat to the incoming cool air, so that, in the gradual replacement of the volume of air around the eggs, little heat is lost.

In addition to this, the earth is a poor conductor the heat, instead of being absorbed, is largely radiated back to the under surfaces of the eggs.

Although the white and yolk of the egg are bad conductors, the shell is an extremely good conductor of heat, and this property greatly assists in the even distribution of warmth to all parts of the egg.

The development of the vascular system in the egg also adds another important aid to the conveyance and uniform distribution of heat from the upper to the under surface, and from the outside to the inside of the egg.

THE TEMPERATURE OF THE HEN.

The bodily temperature of birds is rather higher than that of mammals. The heat of the human body,

as indicated by a thermometer placed in the mouth, or under the armpits, etc., is 98 or 98½, the temperature of the blood itself being about 100. During the first few days of incubation, the heat of the hen's blood near the heart is as high as 112 degrees, gradually lowering during the three weeks to about 110 degrees. A thermometer placed in the rectum of a sitting hen, at first registers about 109 or 110 degrees, by the end of the first week, 108 or 109 degrees, by the the end of the second week, 107 degrees, and by the end of the third week, 106 degrees. The temperature registered close under the abdomen, in the middle of the nest, and on the top of the eggs, when the latter are thoroughly warmed through, is from 103 to 105 degrees.

THE TEMPERATURE OF THE EGGS.

The temperature of eggs in process of incubation is lower than that of the incubating body, and the amount of this difference or degree of variation between the two temperatures does not remain uniform through all the stages. It is not possible to get the internal temperature of the egg as it is kept by the hen at the various stages of incubation, with perfect exactness, but it has been done with sufficient accuracy for practical purposes.

In the experiments, which gave the results below, the eggs, after being taken from the nest, were wrapped up in warm material, a very small hole was made in the large end of the egg, and an extremely delicate thermometer, previously raised to 98 degrees, was inserted, and its registering noted with the least possible loss of time and heat. About half a degree was added to the temperature registered, an allowance which would fully make up for the unavoidable loss of heat during the testing.

By the end of the first day, the average temperature of a fertile egg was as near as possible 97½ degrees, a slight gain on an infertile egg, which varied little from 97 degrees from the beginning to the end of the incubation period. This is for the whole of the white and yolk, although, in all probability, the germ itself, containing life, and being nearest the scource of heat, if it had been possible to register its temperature, would have been a few degrees higher, say 100 to 101. On the third day, the eggs showed an average temperature of 98½ degrees, gradually increasing till they reached 102 degrees about the end of the second week, at which degree they remained more or less stationary till the time of hatching.

CHAPTER VIII.

ANIMAL HEAT.

The germ is that vital part of the egg which has the power of taking up the nutrient material in the egg, and of incorporating it in the building up of its own structure. The force expended in doing this is supplied from the outside in the form of heat. As the circulatory system of the embryo develops, heat is produced also in the egg itself by the oxidation of its nutritive material, or, in other words, heat is produced by the union of the carbon and the hydrogen in the egg with the oxygen from the air, carried by the blood to all parts of the egg. Carbonic Anhydride (or generally termed Carbonic Acid) being formed in the first case, and water in the second. Although, internal heat, strictly speaking, begins to be generated from the very first day, it is not until about the 11th or 12th day, by which time the structural development of the chick is fairly advanced, that it begins to assert itself. Towards the close of the 20th day, this internal combustion is so great that a much less amount of artificial heat is required in the incubator than was needed at the beginning.

From the foregoing remarks, it will be observed that it is inadvisable to attempt to incubate eggs of

varying ages together in the same incubator, because the eggs placed in the incubator first will continue throughout the incubation period a degree or two warmer than those put in last. If, for instance, the bulb of the thermometer is placed on one of the earlier eggs, and the incubator adjusted to work to 103 degrees, as indicated by that thermometer, the eggs placed in the machine last would be under-heated, a thermometer placed on one of them registering probably 101 to 102½ degrees, notwithstanding that the latter eggs may be thoroughly warmed through. If, on the contrary, the heat of the chamber were raised in order to keep the reading of the thermometer on one of the late eggs at 103 the older eggs would be found, by experiment, to be about 104 or 105 degrees.

CHAPTER IX.

TEMPERATURE OF AIR IN INCUBATOR TO KEEP THE EGGS AT THE REQUIRED HEAT.

It is necessary for successful artificial incubation that the eggs be kept as near as possible at the degree of heat at which they are kept, during the various stages by the hen. The reading of the thermometer,

even though placed on a fertile egg, does not, however, necessarily register the correct temperature of the egg itself, the latter being, in the earlier stages, always from one to two degrees lower, and in the later stages the difference gradually diminishes till, in some cases, the temperature of the egg is slightly higher than the air above it. Neither is it sufficient or safe to be guided, solely, as to the correct temperature at which to keep the air of the egg chamber, by the heat of the space between the fowl's abdomen and the eggs, as the comparatively stagnant volume of warm air, enclosed and held by the down and feathers of the hen (the incubating body being also in actual contact with the eggs) and the open, and more or less moving volume of air above and about the eggs in an incubator are not parallel conditions.

In natural incubation, the incubating body keeps fairly constant, whereas the varying temperature of the outside atmosphere, and consequently, the correspondingly varying temperature at which it is necessary to have the source of heat in an incubator, in order that the thermometer may register a uniform degree, say 103, in the egg-chamber, cause a wider variation between the reading of the thermometer and the correct egg temperature, than is the case under the hen. Experience proves, for instance, that in cold weather,

when the heat in the incubator tank is necessarily high in order to keep the egg-chamber at 103 degrees, the heat of the embryo will be from $1\frac{1}{2}$ to 2 degrees lower in the early stages than the air above it. In hot weather, on the contrary, when the heat in the tank is lowest, the temperature of the air and the reading of the thermometer being still 103 degrees, the eggs will be at from $\frac{1}{2}$ to $1\frac{1}{2}$ degrees lower only. These one or two degrees, marking the difference between the temperature of the egg and the air above, are absorbed, or consumed, as it were, by the embryo in structural development. Growth made, or work done means force, or heat expended, in the same manner as it is absorbed in converting ice into water. Ice at 32 degrees requires heat to transform it into water, also at 32 degrees, the heat which disappears, or is lost to thermometric measurement, being equivalent to the work done. In the later stages of incubation, heat being generated in the shell, less and less is absorbed for this purpose from the outside, till the two temperatures (that of the egg and the air above it) approximate.

It will be evident, therefore, that to secure the best results, the temperature of the air about the eggs in an incubator, should not be quite the same for all conditions of the outside atmosphere. The heat of

the hen's body, certainly, does not vary much, but what, in practice, will apply to the hen, will not, it has been proved, apply equally to the incubator.

Suppose we want to keep the germ of the egg at a temperature as near as possible that at which the hen keeps it, which is is approximately as follows :—

	IST WEEK.	2ND WEEK.	3RD WEEK.
Natural temperature of germ, as kept by the hen	101	102	103
Reading of thermometer placed on a fertile egg, and registering temperature of the air in egg chamber. In cold weather	2 degrees higher than the germ.	1 degree higher than the germ.	o degrees higher than the germ.
Reading of thermometer and temperature to adjust incubator for cold weather	103	103	103

	IST WEEK.	2ND WEEK.	3RD WEEK.
Natural temperature of germ	101	102	103
Reading of thermometer, registering air of egg chamber. In hot weather	1½ higher than germ.	½ higher than germ.	½ lower than germ.
Reading of thermometer, and temperature to adjust incubator for hot weather	102½	102½	102½

These temperatures are based on the supposition that the eggs receive little cooling, and that incubation is continued without check. A good sitter does not often leave her nest, nor stay away long when she does leave, especially in cold weather. When she returns, the eggs are soon brought back to the proper temperature, whereas in an incubator, a considerable time is taken up in heating the air space, and in bringing the heat down to the eggs. If regularly cooled, the development is correspondingly retarded, and a degree or two higher heat will need to be given throughout the term of incubation, making the best temperature in cold weather 104 degrees, and in warm weather 103½ or 103 degrees for the three weeks.

As it is not an easy matter to discriminate between hot and cold weather, the following general rule might be followed with advantage. If the temperature of the room is 40, 50, 60, 70, or 80 degrees, the temperature in the incubator should be adjusted to work at 105, 104, 103, 102, 101½ degrees respectively. The most favourable temperature of the room is between 55 and 65 degrees.

Instead of one average temperature throughout the whole incubation period, it is safer, and generally better results are obtained, by starting with a lower

temperature of about 102 degrees, and gradually increasing it to 104, as too high a temperature, if prolonged, is fatal at any time, but especially in the earlier stages. After the first twelve or fourteen days, the chick can bear greater vicissitudes of heat and cold, the structural development of the chick being so advanced, that it is able, to a small extent, to dispose of surplus heat in the same manner that it does after it is hatched ; near hatching, any reasonable excess of heat can be borne for a short time, without fatal results.

CHAPTER X.

COOLING THE EGGS.

Regular cooling is not a necessary condition to secure good hatches, provided the incubator is ventilated on a correct principle. There must be neither too much ventilation nor too little, as the former will chill, and kill the germs, and the latter will suffocate them. Far more chicks are killed by too much of this cooling process than by too little.

The saying that " A close sitter (that is one that does not often cool her eggs) is a bad sitter " is not

well grounded and will as often be found to be untrue as true. A hen gets off her eggs, in addition to when hungry or thirsty, when she feels that they are overheated and this is necessary or the chicks would be weakened by excessive heat. Hens are probably like human beings in that the amount of heat different hens can bear without discomfort varies. Some hens are possibly not inconvenienced by excess of heat, and, by sitting too closely, hatch badly. On the contrary, if the nest be in an exposed position, scantily provided with warm bedding, or the weather cold, or if there are many unfertile eggs in the nest, and in consequence a small amount of naturally-generated heat from the fertile ones, or the sitter is not in the best physical condition for imparting heat to the eggs, a close sitter under these circumstances would probably be more successful than one that frequently left her eggs. To put it briefly, a close sitter is *not* a good sitter, if, from any cause, she permits her eggs to get overheated ; and, on the contrary, a close sitter *is* a good sitter if, owing to her circumstances, it is necessary to sit closely to keep the heat of her eggs up. The saying "A close sitter is a bad sitter," seems to infer that close sitting necessarily *causes* bad hatches, whereas poor eggs or unfavourable conditions are the *cause* of the bad hatch, and the close sitting the

effect produced instinctively on the hen ; that is, the bad hatch is *not* necessarily the *effect* of the close sitting. As a rule the close sitter is merely trying 'to make the best of a bad egg.' The converse is also true. These remarks do not apply to the loose sitting caused by the irritation of vermin, etc.

A hen left to herself, with food and water within easy reach, will seldom leave her eggs, especially in cold weather, often not exposing them for two or even more days at a time, and when she does leave them they are quickly raised to the requisite temperature again on her return. In an incubator, the case is different. In cooling the eggs, the egg chamber is also cooled, and it takes one, two, and in some cases, three hours to get the eggs warmed through again. The eggs are better not allowed to cool below 80 degrees, and while this is being done, the incubator should be closed to keep in the heat as much as possible. This is supposing, of course, that the machine is properly ventilated, and the air not polluted by the odour of decaying germs. In hot weather a little cooling may not only be permissible but even beneficial, but it should be so performed that, when the eggs are replaced, they are brought back to 103 or 104 degrees within the hour.

In the early stages, before the embryo has begun to

generate much animal heat, the eggs will lose, when the temperature of the room is about 60 degrees, about half a degree for each minute of exposure, and with an atmospheric temperature of 40 they will cool at the rate of about a degree per minute.

It is possible that by the cooling of the egg, and the consequent contraction of the air within it, an extra absorption of oxygen takes place, which benefits the chick.

CHAPTER XI.

INCUBATION PERIOD.

As before stated, 21 days is the normal incubation period, but the actual period varies considerably with circumstances. The eggs of the lighter breeds hatch out sooner, other conditions being equal, than those of the heavier breeds.

There exists in the germ the latent energy, which only requires a sufficient degree of warmth to endue it with growing power, and in cases where the egg has been held from fright, or other cause, in the oviduct of the hen, development of the germ has been, even at the time of laying, several days advanced, hatching out, apparently, as early as the 18th day.

Germination will commence, and proceed slowly at the comparatively low temperature of 80 degrees, and may be retarded in its development, by a low temperature, or by frequent cooling, as to lengthen the period to 23 or 24 days, but it is obviously apparent that if the vital spark is stimulated from its dormant state, and its activity once arrested, its life becomes finally extinguished.

The figures below give the average number of days required to incubate the eggs of the following birds:—Hen, 21 days; duck, 28; goose, 30 or more; turkey, 28; pheasant, 24; partridge, 24; peafowl, 28; swan, 58; ostrich, 42.

CHAPTER XII.

KEEPING EGGS FOR INCUBATION.

The best temperature at which to keep eggs intended for incubation must obviously be below the heat that would arouse the latent vitality of the germ into activity, and experiments have revealed the fact that a prolonged temperature of even 65 degrees will cause slightly perceptible changes in the germ. On the other hand, the low temperature of 32 degrees

would, by freezing the water of the egg, so break up its structure and cell arrangement as to be fatal to the future development of the chick, and would probably also kill the germ itself. As the temperature lowers, the volume of the egg contracts till it reaches 39 degrees, at which temperature the water, composing a large percentage of the white and yolk, is at its greatest density. From 39 degrees, expansion sets in, increasing rapidly to the freezing point (32 degrees). As the first effects of freezing are, therefore, felt at 39 degrees, it is evident that 40 degrees is the lowest temperature at which eggs can be kept without risk. From 40 degrees to 60 degrees is obviously, therefore, the limit, and, probably, the nearer the lower temperature, the better.

CHAPTER XIII.

THE POSITION IN WHICH TO KEEP EGGS RESERVED FOR INCUBATION.

Varied opinions are expressed as to the best position in which to place eggs reserved for incubation. Large end downwards, small end downwards, laid on one side and turned daily have each their advocates.

The yolk, being of less density than the albumen, has a tendency to rise to the top, gradually forcing aside the albumen above it, and, if allowed to remain long in one position, the thin layer of albumen left dries, and the germ becomes glued to the shell. The drier, or warmer the atmosphere the quicker this adhesion takes place. The chalazæ, to which the yolk is attached, being the densest part of the egg, counteracts this upward force, to some extent, by tending to drag the yolk down. Too high a temperature also renders the albumen more fluid, and consequently more easily pressed aside. It is thought by some that by placing the large end of the egg downwards, the weight of the contents presses on the air chamber and, by preventing its enlargement, retards loss of moisture by evaporation. But this argument is not tenable, as evaporation of the water of the albumen takes place not only from the air space, but through all the pores, no matter in what position the egg is placed.

As the aim in preserving eggs is to prevent loss of moisture by evaporation (the germ never sticking to the shell till the eggs are well dried down), the best, and, in fact, the only way, is to keep them in a cool place, not too dry. They should be covered with a cloth to check evaporation, and turned daily.

The following method has been proved by experience to be as effective as any for preserving eggs for incubation, but the same measure of success must not, *by any means*, be expected from such eggs as from fresh ones.

Wrap up each egg in a square piece of damp proof paper in such a way that all the edges of the paper are drawn to one end and tightly twisted, thus excluding the air. Grease-proof or butter paper, which may be obtained of most grocers, is suitable for wrapping the eggs. Pack the latter, so wrapped, small ends up, tightly into conveniently sized boxes, and when full, screw down the lid and date the box. If moderate sized boxes are used, those filled first can be opened first for use. Keep the boxes in a cool, dry place, and turn over every day. Eggs have been preserved in this simple way for nearly a year, and have afterwards hatched chickens. Great care should be taken that the eggs put down are perfectly fresh, but they should not be wrapped up and packed in the boxes warm from the nest. Allow them to cool first.

The hen, and many wild birds, require three weeks or a month to lay a batch of eggs before commencing to sit, leaving them during the greater part of that time exposed, and the earliest-laid eggs usually hatch as well as the latest laid, but for some unexplained

reason, eggs reserved the same length of time for artificial incubation, give far less satisfactory results than fresh eggs. It has been suggested that the daily warming through that a hen, laying away, gives her eggs, in some way resuscitates them and preserves their vitality, but it is probable that the usual location of a stolen nest, being on more or less moist ground, shaded from the sun, and sheltered by vegetation from drying draughts, together with the fact that the hen generally shuffles her eggs every time she visits the nest, and that the eggs are, as a rule, of uniform and vigorous vitality, offer a much better explanation. Dirty eggs are not good for incubation, neither are washed eggs advisable.

CHAPTER XIV.

HEAT AND ITS PROPERTIES.

What heat is, is not known, but the generally-accepted theory is, that it is an immaterial force in the form of vibrations in the molecules of matter, the quicker the vibrations the greater the heat, and *vice-versa*. These heat vibrations may be transmitted from one body to another, and tend to diffuse equally

among bodies of different temperatures, the quicker vibrations of a higher heat tending to impart their own rate of movement to a body at a lower temperature, and, in so doing, retard or lessen the velocity of their own.

Heat may be transmitted in three ways, either by conduction, convection, or radiation.

CONDUCTION OF HEAT.

In conduction, the vibrations are transmitted from one molecule to the next in actual contact, as would be the case if one end of a piece of iron were placed in the fire.

CONVECTION OF HEAT.

By convection, which applies only to gases and liquids, heat is bodily conveyed from one place to another, generally a higher place, a cooler volume of the gas or liquid taking its place, resulting in a circulation of heat, as when water is boiled on the fire, the hot water rises in the centre of the vessel, and the cooler water descends by the sides.

RADIATION OF HEAT.

Radiation is the transmission of heat from one body to another by means of the heat vibrations in an intervening body. This heat travels only in straight lines as in the case of warmth radiated through the intervening air from a fire.

CHAPTER XV.

DIFFERENCE IN THE CONDUCTIVITY OF BODIES.

The more solid the body, or, in other words, the closer the atoms, the more readily are the molecular heat vibrations transmitted. On the contrary, the looser and more porous a body, the less its powers of conduction. The latter substances are termed, generally, bad or non-conductors, though, strictly speaking no material is entirely non-conducting. All liquids and gases possess small conducting power. If, for example, boiling oil is gently poured on the top of a vessel of water, the heat will make its way to the bottom extremely slowly. The advantage, for the purpose of packing incubators, etc., possessed by such substances as fur, wool, wadding, etc., is that they do not possess the necessary continuous line of atoms in contact, along which to transmit these molecular vibrations. There is, alternately, a solid and an air space, and air being a bad conductor, the vibrations are checked or resisted in their course.

In using packing between the cases of an incubator for the purpose of conserving the heat, it may be noted that pressing it too closely, by lessening the air spaces and making it partake too much of the nature of a solid, diminishes its value as a barrier to

the passage of heat. On the contrary, air, although a bad conductor, is a good conveyor of heat, and if the packing is too loose, by leaving too much air space, heat is rapidly carried or diffused by little currents through the packing.

CHAPTER XVI.

DISTRIBUTION OF HEAT IN, AND VENTILATION OF INCUBATORS.

When a gaseous or liquid body is heated at the bottom to a temperature higher than that of the gas or liquid above it, it becomes, by expansion, of less density, or lighter, and rises to the surface, the colder, and therefore heavier air or liquid falling to take its place. In an incubator, however, the air is warmed by contact with the heated tank on the top. This heated air becomes lighter than the air below, and, as a consequence, cannot descend in a current to the eggs, but remains floating on the top, buoyed up by the denser air below; its means of imparting its heat to the air on a level with the eggs being chiefly by radiation, the molecular heat vibrations, owing to the mobility and rarity of gaseous bodies, being readily diffused downwards.

We will now consider the subject of the distribution and equalization of heat in the incubator. Practically, all machines are heated either by a hot-air or hot-water tank, which generally covers the entire top of the egg-chamber, but, although this tank may radiate from all parts of its under surface heat of exactly equal power, it does not follow that the air on a level with the eggs will have the same very desirable uniformity of temperature. The equalization of heat over the comparatively large area of the egg-chamber is a difficulty not easily overcome, and in many machines the temperature, if tested by thermometers in various parts, would be found to vary many degrees.

The eggs in natural incubation are not kept at a uniform temperature, those in the middle of the nest being from one to three degrees warmer than those near the edge, but it would not be a wise proceeding to copy nature too closely in this respect.

In the first place, the under surface of the heating body cannot, in practice, be got to a perfectly even temperature in every part. If the tank, or hot-air reservoir could be kept at the requisite and uniform temperature, and the eggs placed in contact with it, as in nature's method, the central ones, especially if the number of eggs were large, and after they had begun to generate animal heat in themselves, would

get overheated by many degrees, owing to a lack of ventilation and a too great obstruction to the outflow above the eggs of heated and, more or less, vitiated air. The same remark would apply to eggs under a hen, if the number were, say, one hundred, as in an incubator, instead of about thirteen. In artificial incubation, ample air above the eggs is essential, and tends, by its mobility, to distribute and equalize the heat of the radiating body. Especially is this the case in incubators in which the fresh air is admitted above the eggs, and allowed to escape under the eggs. When the ventilation is from inlets under the eggs to outlets above the eggs, this even distribution of heat on the level of the tops of the eggs is less easy of attainment. The tank, or source of heat may remain constant, but the air space immediately below the eggs will vary, especially by the latter method of ventilation, almost half as much as the outside atmosphere. This want of correspondence between the temperature of the tank and the air space below, increases rapidly the further we recede from the tank. In other words, if the heat of the tank were allowed to remain constant, the temperature of the egg-chamber below it, would rise and fall according to the temperature of the fresh air coming in from beneath. When fresh air is admitted above the eggs,

the air space maintains a temperature much more in sympathy with the source of heat, and less in sympathy with the outer air, and, if the former remains constant, the egg chamber will not vary very much.

Then, again, so long as a perfect non-conductor of heat does not exist, no matter what material is used for packing, or how thick the walls are made, the sides of the incubator will always absorb some heat, and, as a consequence, the eggs near them, if on the same level as the centre eggs, will always be in a perceptibly lower temperature than those nearer the middle. The corners will have a lower temperature still, because, not only is there the loss of heat by the absorption of extra wall surface, but in addition, although heat is radiated in straight lines, from the heated source above, the heated air itself, which acts as a heat-equalizing agent, moves, more or less, in eddies or circles, and the corners are consequently missed. Round incubators would overcome this fault, but the shape is inconvenient in a hot-water tank machine, which requires to be opened at the side. Moreover, they cannot easily be constructed except of metal, which absorbs heat much more rapidly than wood, unless thickly covered with non-conducting material.

CHAPTER XVII.

DEVICES TO RENDER THE DISTRIBUTION OF HEAT EVEN.

Many devices are adopted to render the heat near the sides of the egg-chamber as near as possible equal to that in the centre. In many incubators the egg-tray is dished, or hollowed, as in the natural nest, which brings the outer eggs nearer the source of heat, and partly counteracts the loss of heat by the absorption of the walls.

In another incubator the under surface of the tank is higher in the centre than at the sides, and as, in this case, the egg-tray is level, the same object of getting the central eggs further from the heat is effected as by dishing the egg tray.

Then, supposing both bottom of tank and egg-tray are level, the sides of the latter may be kept nearer the temperature of the centre by directing the heat supply in such a way as to heat the sides of the tank to a higher degree than the centre.

None of of these devices, neither the dishing of the egg-tray, nor raising the centre of the under surface of the tank, nor heating the sides of the latter to a higher degree than the centre, are so effective in equalising the heat as well-made non-conducting

walls, with draught-proof door. If the hot air in the incubator is banked up with such walls, the heat will be sufficiently even for all practical purposes, and quite as uniform, probably, as it is under the hen.

The colder the weather the greater will be the absorption of heat by the walls, and consequently the greater the inequality of heat between the sides and the centre.

CHANGING THE POSITION OF EGGS IN INCUBATOR.

From the above remarks the necessity there is for changing the position of the eggs, in addition to turning them over, will be apparent. It is, as we have seen, practically imposible to maintain a perfectly even temperature in every part of the egg-chamber, and if the same eggs were allowed to remain throughout the whole incubation period in the same positions, they would not hatch out as well, or as regularly, as would be the case if their places were changed daily. Many of the eggs in the cooler parts of the machine would probably succumb, in consequence of continuous under heat, or, at the best, hatch out behind time, while others, in the hotter parts of the incubator, might be killed outright by a continuous temperature a degree or two too high. Eggs of average vitality can easily bear a slightly higher, or lower temperature than 103 or 104 degrees, if not too prolonged, and

this regular changing of their positions from the warmer to the cooler parts of the incubator, causes the chicks to develop more equally, and to hatch out more regularly.

No egg-turning apparatus, which does not permit of this change of location of the eggs is of any use. The best arrangement is one by which the eggs may be turned over by some mechanism without the jarring consequent on careless or hurried handling, and then the whole tray or drawer reversed.

THE EFFECT OF INFERTILE EGGS IN INCUBATOR.

Another circumstance causes inequality in the amount of heat received by all the eggs in an incubator. It will be said, however, that in natural incubation the same fact often applies, but we cannot afford to copy nature, except under her best and most advantageous conditions, when every egg produces a live chick, and our degree of success in artificial incubation depends more upon our being able to give to all the fertile eggs of the same age an exactly equal temperature than upon any other condition.

We will suppose that the air in the egg-chamber is kept uniformly at 103 degrees throughout the three weeks. For the first week or more, the fertile and infertile eggs alike absorb the warmth in practically

the same degree. After about the eleventh day, the fertile eggs begin to generate a natural heat, which rapidly increases in amount to hatching time. The infertile eggs, however, do not increase in temperature after the first day, and never get higher, while the air above them remains constant at 103 degrees, than from 99 to 100 degrees. Suppose then, say, on the 18th day, a fertile egg is surrounded by infertile or addled ones, the latter will continually absorb or drain, as it were, the heat from the fertile one. The reading of a thermometer placed on a fertile egg surrounded by other fertile eggs, will always register slightly higher, than the reading of a thermometer placed on a fertile egg surrounded by infertile ones. For this reason, it is very essential that all infertile and addled eggs should be removed as soon as possible, that all the remaining fertile ones may have an equal chance. It will also be evident, that to indiscriminately mix eggs in different stages of incubation is not conducive to the highest measure of success, inasmuch as the older eggs, being warmer, will always lose a portion of their heat to those added later, and in doing so, their vitality is impaired. It is not a very difficult matter for delicate fingers to tell, after a little practice, a fertile egg a fortnight old, from an infertile or addled one, by the sense of touch. To work the

incubator at the correct temperature, it is very important that the bulb of the thermometer should rest on a fertile egg, or, at least not on an infertile one, as the difference in temperature between an egg just about to hatch, and an infertile one, will be as much as three or more degrees. In practice, when not convenient to distinguish between live and dead eggs, let the bulb of the thermometer be placed about one-eighth or one-quarter of an inch above the eggs.

CHAPTER XVIII.

THERMOMETERS.

As so much of one's success in artificial incubation depends upon having a correct thermometer, and as many of the cheap ones sold are entirely unreliable and worse than worthless, a few words in regard to them may not be out of place. Thermometers should have the degrees marked on the tube, as the cheap ones, mounted on wood or metal, have the scale stamped on the latter by the hundred or thousand at a time, the sealed glass tubes being afterwards fitted to them. The rise and fall of the mercury in the tube may, or may not coincide with the scale on the mount already prepared, in some cases the reading being several degrees out.

Even thermometers etched on the stem are not necessarily reliable. After being sealed they should be kept a considerable time before being scaled, otherwise the subsequent contraction of the glass tube causes the mercury to rise a degree or more in its registering above the correct temperature. Any thermometer, however, may be used in an incubator, after it has been tested by comparison with one known to be correct, if proper allowance is, of course, made for the amount of its inaccuracy.

To test a thermometer, place the bulb as far into the mouth as convenient and close the lips. If, in this position, it registers between 97 and 99 degrees it may be considered as approximately correct.

Most thermometers have a small expansion chamber at the top of the tube, in which, occasionally, a little mercury lodges. A globule here, almost invisible to the naked eye, is sufficient to make the reading one or two degrees less than the correct one. If the mercury should get divided, place the bulb of the thermometer in warm water, gradually increasing the heat with hot water, till the mercury rises into the expansion chamber. A gentle tap on the top of the thermometer, as it cools, will probably join the disconnected portions.

CHAPTER XIX.

CIRCULATION OF THE BLOOD.

As the essential object of ventilation is the supplying of pure air for the purpose of aerating the blood, a brief desciption of its circulation may assist in making the subsequent observations clearer. By the rythmic contraction of the muscular walls of the heart, the blood is driven out of its cavities into the arteries, which divide and subdivide into minute capillaries, the latter ramifying into every part of the body. From the capillaries, the venous, or impure blood is conveyed back to the heart by the veins. Nutritive matter is absorbed through the delicate walls of the capillaries surrounding the alimentary, or digestive tract, into the blood, by which it is carried to all parts of the body, to build up and repair its organs and tissues. From these organs, the blood returns by the veins, charged with waste products, in the form, chiefly, of carbonic acid, water, and organic impurities to the lungs, skin, and kidneys. From the lungs, which have a double function, carbonic acid and water are exhaled, and the blood is again aerated by fresh supplies of oxygen.

RESPIRATION.

Respiration consists simply of the absorption of

oxygen and the exhalation of carbonic acid and water. Oxygen is carried by the corpuscles of the blood and unites with the carbon and hydrogen of the waste and decaying tissues forming, by the first combination, the above-mentioned gas (or, more strictly speaking, Carbonic Anhydride, CO_2) and, by the second, water, (OH_2). The carbonic acid in the impure blood is given up to the air in the lungs in obedience to the law of the diffusion of gases, which, briefly explained, is this. It is well known that liquids of varying densities or specific gravities, when poured together into a vessel, will arrange themselves in the order of their densities, the heaviest subsiding to the bottom and the lightest floating on the top. Gases, however, do not follow this law. If several gases are mixed together, as in the case of the oxygen, nitrogen and carbonic acid of the atmosphere, each gas, irrespective of its density, diffuses itself uniformly through space, or, in other words, behaves as if no other gas were present. The gas chlorine is thirty-six times heavier than hydrogen, but if equal volumes of these are placed together, say in two bottles, joined together at the neck, chlorine in the lower, and hydrogen in the higher, in a few hours it would be found that the two gasses were perfectly mixed. Moreover, the more widely the densities differ, the quicker is this uniform diffusion effected.

Therefore, the less pure the blood is in the lungs, or the more it is charged with carbonic acid and the purer the inhaled air, the wider the difference between the two as regards the relative amount of carbonic acid contained in each, and, consequently, the more rapid will be the exchange of the latter gas into the air cells to be exhaled, and of oxygen into the blood, or in other words, the more rapidly will the carbonic acid be eliminated.

Although carbonic acid in the air may not be, in itself, directly poisonous, it certainly becomes indirectly so, when, by its presence in the air cells, only a small amount of it is necessary to be given up to render the diffusion uniform, a more or less large quantity of this gas being retained in the blood to the exclusion, or displacement of the vitalizing agency of oxygen. The normal amount of carbonic acid in the atmosphere may be assumed to be harmless, but any increase is deleterious, inasmuch as, in the same ratio as it increases, oxygen is excluded.

In the vegetable kingdom, the chemical action is reversed. Plants, under the action of sunlight, decompose the carbonic acid, or carbonic anhydride (CO_2), absorbing the carbon and liberating the hydrogen. This, and the tendency of injurious gases to diffuse away, and to become gradually weakened, and the

action of rain in absorbing and washing down impurities, tend to keep the atmosphere pure and fit for respiration.

RESPIRATION OF THE EMBRYO.

Respiration consists, as we have seen, of an interchange of gases between the air and the blood. With the commencement of incubation, the germ begins to absorb or breathe, as it were, oxygen through the porous shell and lining membrane of the egg. The latter contains, within itself, in a latent form, all the elements necessary, including sufficient moisture, for the production of a chick, except oxygen, and even of this element, there is sufficient for the first twelve to twenty-four hours of the germ's life, without imbibing any from the outside. This is proved by the fact that a varnished egg, impervious to air, will commence to germinate, and will live for some time.

At first, the germ draws its nourishment directly from the white and yolk immediately surrounding it, but, as it grows, its requirements become too large to be satisfied in this way. A circulatory system of blood-vessels is gradually developed, by means of which nutrient material is absorbed into the blood from all parts of the egg, but especially from the white, and is conveyed to the germ. The vascular

system also surrounds the white, where, being exposed to the outer air, through the porosity of the shell, a sufficient quantity of oxygen is taken up, and carbonic acid and water, the products of the chemical action or combustion in the egg, are discharged.

CHAPTER XX.

VENTILATION AND HUMIDITY UNDER THE HEN.

Although a free interchange of gases, or good ventilation is an absolute necessity for the development of the embryo, anything approaching a continuous air current to attain this end, is almost as bad an alternative. Under a sitting hen, the diffusion of fresh air inwards near the bottom of the nest, and of heated air, charged with carbonic acid and some moisture, outwards on the tops of the eggs, is imperceptibly gradual, the air being impeded in its passage by the down and feathers.

This slow replacement of air is important for several reasons. We know that moving air, even of the same degree of humidity, absorbs more moisture than air in a state of quiescence. If the air under a hen circulated, or moved as rapidly, as it is permitted

to do in some incubators, the water in the egg, which forms such a large proportion of the total weight of the chick, would be too rapidly evaporated, and the growth of the embryo would cease.

The air around the eggs does not exercise this drying effect, and is kept sufficiently humid from another cause. The cold air from outside comes into the nest charged with an amount of moisture varying in accordance with the state of the outside atmosphere. As it becomes heated, its capacity for holding moisture is gradually increased. It consequently absorbs the water given off by the eggs during their development. Having reached its maximum heat, it commences its outward journey through the feathers, gradually cooling by coming in contact with the incoming air. In doing this, it not only loses some of its warmth, but, with it, also its capacity for retaining all the moisture with which it was charged when at its maximum temperature; or, in other words, by simple diffusion, the incoming air receives moisture from the outgoing air, the latter leaving the nest with only a small increase of heat and humidity from what it had when it entered the nest. The comparatively small amount of moisture leaving the nest only approximately keeps pace with the natural exhalations given off as the

chick develops, no water being forced from the egg by either dryness, currents, or undue heat in the surrounding air.

Whatever the humidity of the outer atmosphere may be, that in the nest will always be somewhat higher, because of its greater heat, and consequent greater capacity for holding the constant exhalations of water from the eggs, and, therefore, just as the humidity of the outside air varies, so will that in the nest. One conclusion, which is tolerably certain, is that the eggs need to absorb no water from the outside. As before stated, the egg contains all that it requires to build up the chick, except oxygen. What the embryo, however, does demand, is that its moisture shall not be abstracted from it, but that it shall be left to the egg itself to send out the water as the growth of the chick necessitates.

Moreover, as this exhaled moisture is sufficient without the assistance of outside supplies, and as it is always present, independent of the dryness or moisture of the outside air, or the dampness or dryness of the location of the nest, a little consideration will make it evident that, in natural incubation, these two latter considerations, provided they are not extreme, do not affect the hatching. Eggs hatch as well

(other conditions being equal) incubated in a dry or moist nest (if not so damp as to create a constant chilling process on the under surface, by the abstraction of heat from the eggs in evaporating the moisture), or in a moderately dry or moist atmosphere, the ordinary changes in the degree of atmospheric humidity not noticeably affecting the results.

THE SOLVENT POWER OF WATER CHARGED WITH CARBONIC ACID.

Moisture has, in conjunction with carbonic acid, another important duty to perform in incubation in addition to that of keeping the air sufficiently moist to prevent undue evaporation. The calcic carbonate, or carbonate of lime, of which the shell is composed, would be too hard for the chick to extricate itself, if, during the three weeks' incubation, it did not undergo chemical changes to break up, or disintegrate the arrangement of its particles, and thus render the shell more easily broken. Pure water would not do this ; but, when containing carbonic acid in solution, its solvent power is greatly increased, and, being prevented by the feathers from being too rapidly carried away, it has time to do its disintegrating work on the shell before leaving.

CHAPTER XXI.

LAWS OF EVAPORATION.

To make clear the subsequent remarks on the ventilation and moisture supply of incubators, a brief explanation of the subject of evaporation may be given.

Watery vapour is always present in the atmosphere, existing as an impalpable, transparent gas. Even the driest air of the desert contains a small amount. In 100 parts of ordinary air about ·45 consists of aqueous vapour, the remaining 99·55 consisting of oxygen, nitrogen, and carbonic acid gases. The process of evaporation is constantly going on, but the amount varies greatly with circumstances, being dependent upon (1) the temperature of the air; (2) the amount of moisture already in the air; and (3) the rate of movement of the air.

The higher the temperature the greater the capacity the air has for holding vapour in solution, there being for every degree of temperature a definite quantity that can be held in invisible suspension, on reaching which state, the air is said to be saturated, or to have attained its point of saturation, and, if further moisture were added, the surplus would

become condensed in a visible form. For instance, air at 50 degrees, charged to its point of saturation, will contain less moisture than saturated air at 80 degrees. The nearer the air of any temperature approaches its point of saturation, the slower does evaporation proceed, and on the contrary, the further from its saturation point, the more rapidly will it take up additional moisture.

The warm air of summer has a larger capacity for holding moisture than the cold air of winter, but if the former is moist and already charged almost to its saturation point, evaporation will proceed more slowly than in the cold, dry air of winter. If we represent the moisture in the air, or, in other words, the aqueous tension of the air, at freezing point (32 degrees Fah.) by 1, and the amount of vapour the same air is capable of holding when saturated by 4, its evaporating or drying capacity might be represented by 3. Likewise, if we represent the moisture capacity at saturation point of air at 90 degrees by 20, and the tension, or actual amount of moisture in solution, by 19, its drying power is only 1 ; that is, it possesses less evaporating capacity than the air at freezing point.

The amount of evaporation is also influenced by the rate of movement of the air. Quiescent air soon

becomes charged with moisture to the extent of its capacity, and further evaporation is checked. If, however, a current is set up, the saturated air is carried away, and, being continually replaced by fresh, dry air, evaporation continues uninterruptedly, and at a speed in proportion to the rapidity of the air current.

Evaporation is not only a drying but a chilling process. In the passage of water into vapour, heat is rendered latent, or, in other words, disappears, or is lost to thermometric measurement, in the change from one state to the other, and, so to speak, cold is produced.

CHAPTER XXII.

VENTILATION AND HUMIDITY IN INCUBATORS.

As we have before stated, in natural incubation, as the heated air leaves the nest it parts with much of its heat and moisture to the incoming cool air, thus carrying away a minimum amount of vapour, only as much, in fact, as keeps pace with the amount thrown off by the eggs and the body of the sitter, the air in the nest being always, therefore, slightly

moister than the outer air. In artificial incubation, however, it is hardly practicable to so copy nature, in the matter of ventilation, as to maintain in the incubator a degree of humidity always a little in excess of the outer air. To make this clearer, we will review the methods of ventilation at present in use.

BOTTOM TO TOP VENTILATION.

Take first the case of an incubator in which the fresh air passes from an entrance under the eggs to outlets above. The fresh air enters at a temperature of, say, 50 degrees, passes over the water-pans in the bottom of the incubator at say, 80 degrees, or less, and becomes charged to saturation at that temperature. As it rises in the machine, the temperature rises to 104 degrees, and with it, its moisture-absorbing capacity is increased, a more or less drying effect being thereby exercised on the eggs, especially if the incoming air is not fully saturated (at its incoming temperature) in its passage over the water pans, or if the air passes rapidly over the machine. If, however the fresh air is saturated at 80 or 90 degrees, although it may have, when raised to 104 degrees, capacity to absorb more moisture, it will be sufficiently humid, with the assistance of the moisture given off by the eggs, to prevent undue drying down,

and will coincide very nearly with nature, provided the air current through the incubator is as slow and gradual as through the feathers of a sitting hen.

The passage or circulation of air through a machine, ventilated from below to above the eggs, is more rapid, for a given amount of outlet, than in incubators in which fresh air enters above the eggs. The colder, and, therefore, the denser the outer atmosphere, the quicker will the replacement of air in the machine take place, and, as the evaporation depends as much upon the rate at which the air moves as upon its humidity and temperature, it is therefore evident that the colder the outer air, the more danger there is of the drying of the eggs proceeding too rapidly, which is tantamount to saying that, with a given amount of outlet, the humidity of the inner air varies with the outside temperature to a greater extent with this method of ventilation than when the air is admitted above the eggs. Under a sitting hen, the humidity in the nest varies with both outside temperature and outside humidity ; in artificial incubation, this fluctuation militates against the most perfect success. As the quantity of air passing through an incubator is regulated by the size and number of outlets, without regard to inlets, in cold weather, some of the former should be closed.

TOP TO BOTTOM VENTILATION.

In some incubators, the fresh air enters the chamber above the eggs, where, by its proximity to the tank, and its diffusion amongst the hottest air, it becomes rapidly heated. It descends gradually to the eggs, and is drawn out below through one or more exits. It is easy to see that, by this method, the passage of air through the incubator will be less rapid, and there will be no perceptible current, but there is greater danger of the purity of the air being impaired, unless the exhaust air shaft, which carries the air away from under the eggs is properly constructed.

If the water tray is above the eggs, the incoming air becomes charged with moisture at a high temperature, and as it descends, and cools, its moisture capacity is diminished, and it passes between the eggs without drying them. If, however, on its entrance, the air becomes charged to saturation at the high temperature at the top of the incubator, the vapour will, on cooling in its descent, become condensed into a visible form, which would be as deleterious as too great a dryness, as the eggs would be prevented from giving off the moisture necessary during the development of the chick. To obviate this, the area of the water tray should be gradually

reduced in size, till the amount of moisture absorbed is not so large as to cause condensation. As the incoming air will vary in humidity according to the locality and the weather, and with these varying conditions the necessary amount of artificial moisture will also vary ; best results will be got, if each incubator user finds out for himself, by experiment, just how much moisture to add to the incoming air, according to the particular situation of the machine, and the season, to charge the air with a degree of humidity a little short of the amount that would cause condensation. The amount of evaporation, at any given temperature, depends upon the area of the surface of water exposed, and not upon its volume or depth. For instance, a tray six inches square, or thirty-six square inches, will give off twice as much vapour as one six inches by three inches, or eighteen square inches, irrespective of the depth of either.

VENTILATION BY BOTH INLET AND OUTLETS ABOVE THE EGGS.

In some incubators, the fresh air ascends through a space around the flue, in the centre, and passes out round the sides, by vents immediately above the eggs. By contact with the hot flue, the fresh air becomes heated, and its vapour capacity is increased, but if the water vessel is near the flue, on a level with the

eggs, the incoming dry air becomes rapidly charged, at a high temperature, with moisture, and will not exert a drying effect on the eggs, the probability being that the air will be too moist, unless the water vessel is small in area, or unless a strong current passes through the machine to carry away the moisture, a condition as injurious as too much humidity.

If the water trays are under the eggs, instead of near the flue, being in the colder stratum of air, the evaporation is less, though it is sufficient (as the area of the water trays is, in this case, generally much larger) to maintain the proper humidity, and there is no danger of the bottom of the incubator becoming damp with condensed vapour, as when the air is charged at a high temperature by a water vessel close to the flue. One objection to the latter method of ventilation, that is, where both inlet and outlets are above the eggs, is that it is liable to allow a volume of more or less vitiated, cold air to remain undisturbed in the bottom of the incubator. By this kind of ventilation, and also in bottom to top ventilation, the under surfaces of the eggs are not kept as warm as under the hen, where the radiated heat from the nest is not very many degress lower than the heat from the sitter's body. Top to bottom ventila-

tion keeps the under surfaces nearly as warm as the upper, and has, therefore, an advantage over the other two in this respect.

Recently a new type of machine has been placed on the market, one in which the walls are porous, and consequently permeable to the passage, both inward and outward, of air, sufficient of the latter being provided without danger of draught. The sides of the machine (which is round) consist of a stout wire framework, covered with thick rugging, through which there is a constant interchange of air by diffussion, after the manner the eggs are ventilated under the hen.

AMOUMT OF VENTILATION NEEDED.

Under a sitting hen the eggs do not get much ventilation, but it is gradual, constant and sufficient to carry away the discharged carbonic acid, and replace it with pure oxygen. There is no draught or perceptible current to dry the eggs too rapidly, and there is no stagnation. The health and strength of the chick depend as much upon the purity of its blood before it is hatched as it does after, and its blood cannot be aerated without air. Too much ventilation, by giving a plentiful supply of fresh air, although it will chill and kill many chicks, has the advantage of making strong those that do get out,

but, by causing too much evaporation, it also dries out some of the moisture necessary for the embryo's structural development, and makes the lining membrane too dry, tough and difficult to break, and less permeable than moist membrane to the free interchange of oxygen and carbonic acid gases.

In the incubator the aim is to provide no more ventilation than is necessary to carry away the carbonic acid, and to prevent its accumulation, because the rate at which this gas is generated in the normal development of the embryo is an exact indication of the rate at which it must be replaced by oxygen. Less than this amount would be fatal, and more than this amount, at the best, could be of no use, and, much more, by creating a current, would be injurious in proportion to its excess.

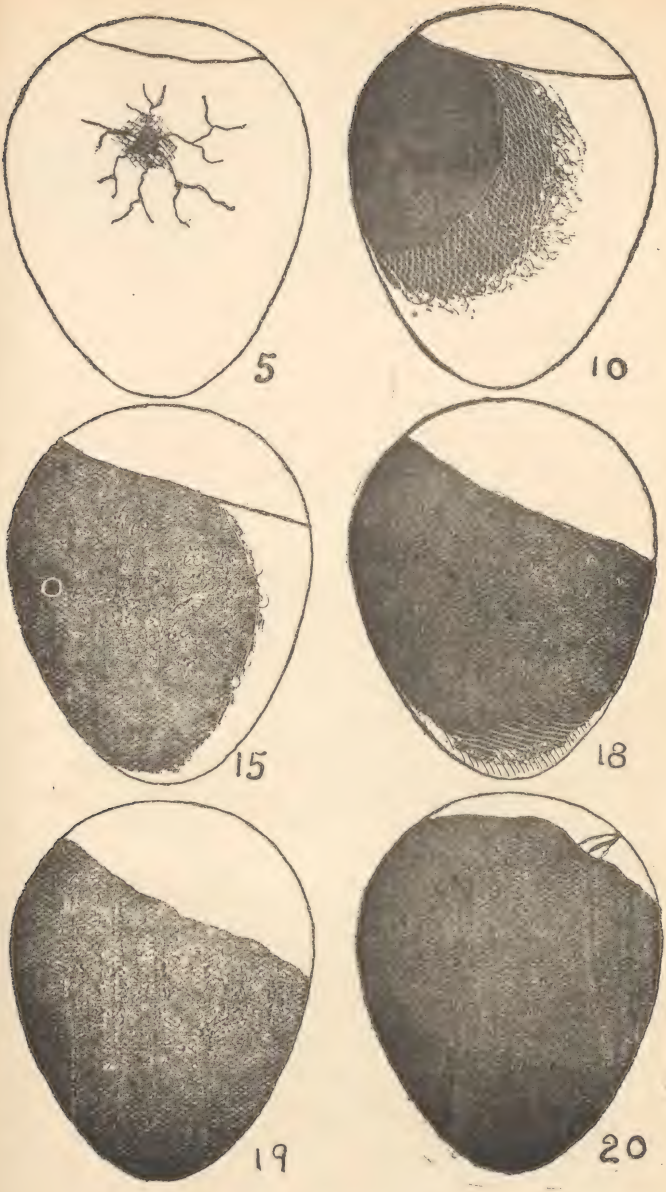
HOW TO ASCERTAIN THE CORRECT AMOUNT OF VENTILATION.

But, it will be asked, how can this particular amount of ventilation be ascertained, and, moreover, the quantity of carbonic acid liberated gradually increases as incubation advances. It is not difficult to gain an approximate idea of the correct amount of ventilation, sufficiently near for all practical purposes. The following is a well-known test for the presence

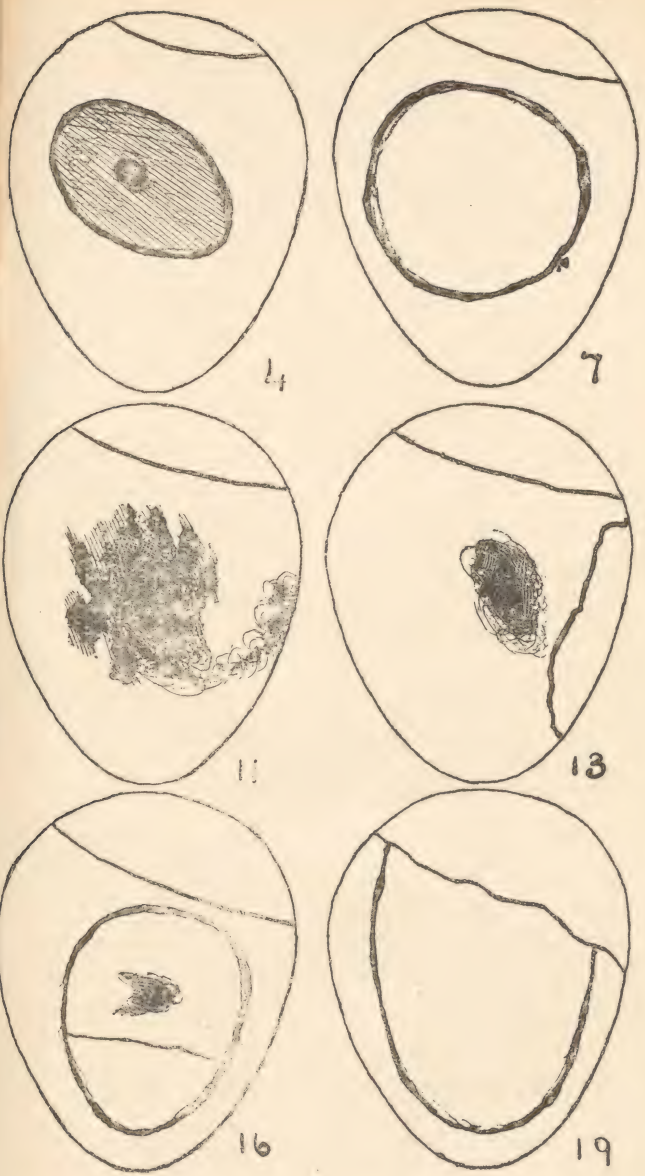
of carbonic acid gas. Lime water, that is, water in which a little lime has been dissolved, and afterwards allowed to stand till clear, has the property of turning milky in appearance with the presence of this gas. In the normal state of the atmosphere there is always about ·049 part of carbonic acid in the hundred, or one part in 25,000 of ordinary air. If this proportion is allowed to increase beyond about ·06 part per hundred, it becomes injurious, and, if much in excess of that proportion, fatal. If air containing a higher percentage of carbonic acid than this, such as the exhaled breath, be blown through a tube into the bottom of a vessel containing lime water, it immediately becomes turbid, or milky. To test, therefore, for this gas in an incubator, place a small glass of lime water in the egg chamber, and gradually increase the fresh air admitted, or, which is the same thing, the number or size of the ventilating outlets, till the water ceases to indicate its presence. For reasons already given, the amount of fresh air required, increases as incubation advances.

Another test that the correct amount of ventilation and moisture is being given, may be made by an examination of the air cells at the various stages of incubation. If the fertile eggs under a hen, sitting under natural and favourable conditions, are

examined, the size of the air cells will be, on the average, as shown in the diagrams on pages 83 and 85. If, on examination, it is found that the air cells are larger, on a given day, than the spaces shown in the illustrations, it may be safely concluded that the eggs are receiving too much fresh air, or, which is in effect the same thing, too little moisture, or, if plenty of the latter, it is being carried away too rapidly. Therefore, to obviate this, or, in a sense, to retard development, lessen the ventilation, and, *vice versa*, when the air cells are too small. The reasons for this are obvious. In the normal development of the embryo, it dries and the air cell enlarges at a certain definite rate, but this rate may be modified, that is, retarded or accelerated by too little or too much evaporation, and the latter depends on the degree of humidity of the egg chamber, or on the rate at which the internal air is changed by the ventilation. The more fresh air given, the more rapid the current, the quicker the moisture is carried away, and the more rapidly do the embryos contract in the shell. The chick, at hatching time, should fill about four-fifths or five-sixths of the shell, the lining membrane should have a dark tinge, the head be pressed loosely under the wing, and the yolk about twice as thick as that of a fresh egg. If, on the contrary, on



Diagrams showing a vigorous Germ as seen through an Egg Tester at the above Stages of incubation. the figures indicating days. These 6 Diagrams show the gradually increasing size of aircell.



Diagrams showing Different Forms of Addled Eggs. All such should be removed from Incubator. These 6 Diagrams show the gradually increasing size of the air cell.

examining a chick about the eighteenth day, the lining membrane is found to be very white and dry, the chick closely bound in the small end of the egg, and the feathers comparatively dry, too little moisture or too much ventilation has been given. To bring these chicks out, more moisture will be required, and more, also, should be used in the next hatch.

In some incubators there is far more ventilation than is necessary, and it is injurious in proportion to its excess. The offensive smell of decaying germs, however, cannot be effectively removed by any system of ventilation, except one which creates a strong current. They must, therefore, be removed, as either fresh air draughts, or stagnant, vitiated air will kill the germs. More on this subject will be found in the next chapter on "Moisture in Incubators."

INDIRECT VENTILATION.

It is not only necessary that the eggs should have enough ventilation, and not more than enough, but it is essential that the fresh air should enter only by the proper channels, otherwise, if cracks, badly-fitting joints, etc., are permitted, the fresh air thus entering, will so disturb the systematic ventilation, and interfere with the even distribution of heat, as to be prejudicial to success. Incubators, with the excessive heat to

which they are subjected, are liable to warp and gape, especially the door, unless they are thoroughly well constructed. When the door, and inlet and outlet ventilating holes are closed, the machine should be so air-tight as to extinguish a burning candle placed within, and, if it is not, it should be made so by pasting up all crevices with paper, and by stopping, as much as possible, the indirect ventilation by the edges of the door.

It often happens that an incubator hatches well for one or two seasons, then, apparently without cause, begins to give poor results. In many cases the cause may be found in leaky ventilation.

CHAPTER XXIII.

MOISTURE IN INCUBATORS.

Experience proves that in incubators an artificial supply of moisture is necessary to secure the best results for reasons previously stated. The egg contains all the water necessary for the chick's development, within itself, the object in surrounding the eggs with a humid atmosphere being to prevent its dissipation by undue evaporation.

Another highly important function performed by moisture is that of absorbing the liberated carbonic acid. At ordinary temperatures water will absorb its own volume of this gas. In summer more moisture is found to be advisable in incubators than in winter, and this is, sometimes, erroneously attributed to the supposed greater dryness of the air, whereas the atmosphere in summer generally contains much more moisture than in winter. By way of illustration, suppose the temperature of the summer air to be 70 degrees, having a moisture capacity of, say, 10. Entering the incubator, this air is raised to 104 degrees, capable of containing, say 20 degrees of moisture. Its drying capacity may, therefore, be represented by the difference between 10 and 20, that is by 10. Now, take the air of winter at a temperature of 35 degrees, with a capacity for holding vapour of, say, only 1 degree. This air is also raised in the incubator to 104 degrees, with an absorbent capacity of 20 as before, its drying effect would thus be 19, or nearly twice as dry as the summer air. It is evident, therefore, that the extra artificial moisture required in summer, which is proved, by experience, to be beneficial, is not necessitated by the dryness of the warmer air. The probable cause is, that, in summer, by the greater sluggishness with which the air is changed in

the incubator, or, the comparative slowness of ventilation, owing to the density of the outer air approaching more nearly that of the inner air, the carbonic acid (or, more strictly, carbonic anhydride) not being carried away as quickly, accumulates more rapidly, and requires more water to absorb it, and to free the air of its narcotic presence.

The different aspects of the subject of fresh air and moisture supply may be thus summarized.

(1) In summer the passage of air through an incubator, with a given amount of outlet, is more sluggish than in winter, the percentage of carbonic acid in the egg chamber increases, which, as shown elsewhere, is indirectly injurious in proportion to the amount of oxygen it displaces. As the development of the embryo depends upon its supply of oxygen from without (moisture, and every other element required existing within the egg), any curtailment of this vitalizing element will check or retard it. In other words, the rate at which the chemical and physical changes in the egg take place, is regulated, within limits, by the amount of oxygen (and warmth) supplied. If development is too slow, owing to sluggish ventilation, the size of the air cell will be, at a given stage, too small, as normally, the embryo contracts in the shell at a uniform rate till about the day before

hatching. By adding artificial moisture, the carbonic acid is absorbed, oxygen takes its place, the growth of the chick is accelerated and the air cell enlarges.

But, it will be said, as the ventilation is decreased, the humidity in the egg chamber is increased, inasmuch as the more rapid the air current, the more drying in its effect it is, and that this extra humidity should, by absorbing the carbonic acid, make up for the slower exchange of air. A little consideration, however, will show, that the extra humidity, resulting from slow ventilation, is got by the moisture lingering longer in the machine, and becoming gradually charged with carbonic acid. The sluggish ventilation, although allowing the moisture, saturated with carbonic acid, to *dwell* in the incubator, does not permit it to *leave* it quick enough. By adding artificial moisture, more carbonic acid is absorbed and carried out, and the air is made purer, but at the risk of rendering the air so damp, that the egg cannot eliminate its moisture during its development, and may even absorb some, thereby causing the chick to occupy too much space in the shell, as shown by too small an air cell. The remedy, therefore, in this case, is to increase the ventilation, which, briefly stated, acts thus : more fresh air, quicker outflow of carbonic acid and replacement by oxygen, egg chamber prevented from becoming too humid, structural growth of chick quickened,

and air cell enlarged. The increased air current, being warm, will not chill the eggs.

(3) In winter less artificial moisture is needed, because, owing to the density of the outer air, the inner air is changed, the carbonic acid carried away, and replaced by oxygen, more rapidly (for the same reason that a fire burns more brightly in cold weather than in warm) development of embryo hastened, and the air cell enlarged.

Care must be taken not to confuse the growth of the structures of the chick, which proceeds at a rate dependent entirely, within reasonable limits, on the warmth to which it is subjected (outside moisture not affecting it) with the space the embryo occupies in the shell. For instance, take two equally well-fertilized eggs on, say, the 15th, day of incubation, both having been subjected to the same temperature of 103 degrees, but one egg having been, all the time, surrounded by vapour-saturated air, and the other, by dry air. The structural development of both embryos would probably be about equal, but, in the former case, the chick would, owing to the more watery nature of the yolk, organs and tissues, be much larger and the air cell much smaller than in the latter case. Probably neither chick would hatch out, the deleterious effects of too much dryness in one case and too much

moisture in the other, proving fatal, the fact becoming apparent only at hatching time by "dead in shell."

About the 17th or 18th day of incubation, the membranous covering of the chick is broken, the inmate, thereby gaining better access to the outer air, commences gradually to use its lungs, the circulation within the lining membrane becomes, at the same time, more and more sluggish, and ultimately dries up just previously to the chick's exit. While too much evaporation of the egg's moisture is generally fatal, the use of too much artificial moisture, on the contrary, by prolonging unduly the drying up of the vessels in the lining membrane, after the commencement of the pulmonary circulation, may so interfere with the vital functions as to cause death. Through the presence of too much vapour, some is absorbed, the membranous blood vessels are kept fluid and active after they should, under proper conditions, have ceased to act.

If the heat of the incubator remains constant, structural development will, on the average, proceed at the proper rate, the air cells increasing in size at a corresponding rate. The size of the latter, therefore, shows whether too much or too little moisture is being used, as either is deleterious. A little allow-

ance, however, must be made for the fact, that the air cells of old and thin-shelled eggs are somewhat larger than those of perfectly fresh, and brown, thick-shelled eggs. As the amount of moisture, or the drying power of the air depends largely on the ventilation, the moisture supply can be regulated either by adding, or withdrawing artificial moisture, or, to a limited extent by lessening or increasing ventilating outlets.

In natural incubation the eggs are not dependent upon any outside supplies of moisture to obviate the danger of undue evaporation, as they hatch equally well in reasonable dry or damp locations, or in any of the varying degrees of atmospheric humidity, but in artificial incubation the case is different. If half a dozen eggs containing live chicks, within about a day of hatching are taken from under a sitting hen, and half a dozen similar eggs be taken from an incubator and placed in warm water, it will be noticed that, on the incubator eggs, small bubbles will immediately form on the submerged portions of the eggs, and, as these bubbles rise to the surface, the eggs sink, whereas, on the naturally incubated eggs, no such bubbles form. This difference in behaviour is easily explained. The latter eggs become coated with an oily secretion, giving them a glazed appearance,

which, though penetrable sufficiently to air, render eggs much less porous, and so checks the diffusion of moisture through the shell, either inward, when the outer air is too damp, or outward, when the outer air is too dry. The incubator eggs have not this oily protection, and, being more porous, the water enters, pushes out the bubbles of air, and the chick is drowned in the shell. If it were possible to find a hen that could sit three weeks on its eggs without giving them this oily coating, that is, if it were possible to keep them in the same porous condition of incubator eggs, it is probable that very indifferent success would be the result, as the eggs would be far more at the mercy of the humidity of the location of the nest, and of the atmosphere than is the case in nature. As we do not know how the natural method of checking evaporation could be applied to artificial incubation, the only means we have of effecting the same purpose, is by charging the air with moisture sufficiently to deprive it of its tendency to absorb more.

THE FOLLOWING DESCRIPTION OF EVERALL'S HUMIDITY GAUGE

(J. B. Everall, Andoe Road, Clapham Junction). is taken from "Incubators and their Management" * (L. Upcott Gill, London) by the author of this book.

"The amount of moisture recommended by different incubator makers and operators as desirable to secure

best results varies widely. Moreover, until this excellent little instrument was put on the market there was no convenient and at the same time reliable method of ascertaining the exact degree of humidity actually present, as this depends upon so many conditions, namely, the moistness and temperature of the incoming air, the rate at which it passes through the machine, the position of the water-supply, the area of the latter exposed to evaporation, the stage of incubation, etc. The amount of water evaporated is a very unreliable measure of the drying effect, or otherwise, of the atmosphere of the egg chamber.

"Everall's Humidity Guage, or Hygrometer, is a modification of the wet and dry bulb thermometer. The latter consists of two thermometers, the bulb of one is covered with muslin, which is connected by means of a thick strand of cotton, with a vessel of water ; the cotton sucks up the water to the muslin enclosing the bulb, just in the same way that the wick of a candle sucks up the melted wax or fat. When the water passes from the state of liquid to that of vapour, heat is absorbed. A drop of water on the hand, in its evaporation, produces the sense of cold, spirit of wine and ether producing even greater cold, because of

* Post free 1/2 from J. H. Sutcliffe, Felliscliffe, Ripley, Leeds.

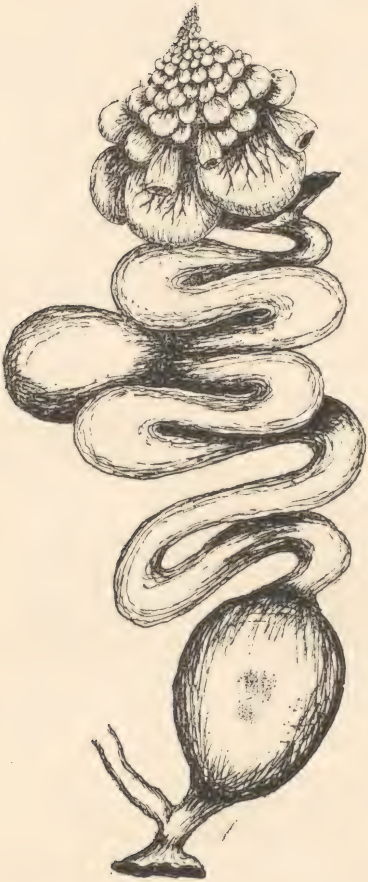
their greater volatility. Owing to the loss of heat, by evaporation, from the muslin enclosing the bulb, the heat registered by this thermometer is lower than that of the exposed thermometer. If the air were charged with moisture to the extent of its capacity, or, in other words, if it were saturated, no evaporation would take place from the covered bulb, consequently there would be no loss of heat, and the two thermometers would register alike. On the contrary, if the atmosphere were very dry, evaporation from the covered bulb would be great, the resultant loss of heat would also be great, and the difference in the readings of the two thermometers would be wide. As a thermometer is provided with every incubator, and as it is only necessary to register the humidity at the temperature of 104 degrees, Everall's Incubator 'Humidity Gauge,' dispenses with the uncovered thermometer, and in place of the covered thermometer above referred to, a hygrometer, measuring the degree of humidity at 104 degrees only is used. It acts in this way : when the exposed incubator thermometer reaches 104 degrees, and, for the sake of illustration, should the moistness of the egg chamber be exactly midway between perfect dryness and saturation, that is, if it should have a humidity of 50 per cent.—the reading of the mercury would be indicated on the scale at the figure 50. Again

the incubator thermometer being still at 104 degrees, if the air should be damper,—containing, say, 70 per cent. of its full moisture capacity—less evaporation would take place from the covered bulb, less heat would be lost, and the reading of the hygrometer would be higher, namely, at 70. The instrument is scaled from 50 to 80.

THE FORMATION OF THE EGG.

All animal life is developed from eggs, with the difference that in most animals, the whole process of development is effected in the body of the female ; while in the case of birds, the process is completed after the egg has left the body.

Attached to the fowl's spine is the ovary, which consists of a collection or cluster of yolks or ova in all sizes and stages of development. Each yolk is enveloped in a sac or bag of thin transparent membrane fastened to the ovary by a stem. As the yolk increases in size this membrane becomes thinner and thinner, especially round its widest part, where it ultimately ruptures, liberates the enclosed full-sized ovum, and discharges it into the funnel shaped entrance to the oviduct, or egg-passage, whose duty it is to conduct the egg to its exclusion. When the yolk bursts its sac and enters the oviduct it is enclosed in a very thin membrane.



OVARY AND OVIDUCT.

The oviduct is a passage about two feet in length. As the yolk passes along this, it is coated first with layer upon layer of albumen, or white, secreted by the mucous membrane of the passage, next, with the double membrane, which lines the interior of the shell, and lastly, with a calcareous deposit or shell. This deposit of carbonate of lime to form the shell is often mixed with colouring matter, which gives the eggs either a tinted or spotted appearance.

If the yolks are liberated faster than the oviduct can secrete the shell, a soft egg is the result. Sometimes after the supply of yolks is finished, the secretions from the oviduct continue active, resulting in a small egg consisting of white and shell only, and which generally indicates the end of a term of laying, or batch of eggs

Should the oviduct become inflamed, checking the secretions, while the supply of yolks continues, one or more of the latter without any covering whatever, may be laid.

FERTILIZATION OF EGGS.

The vital fluid, or sperm cells of the male consist of microscopic threads, one end of which is slightly enlarged. These sperm cells pass along the oviduct to the ovary, and there await the bursting of the yolk

sacs and the liberation of the ova. Each yolk has a minute opening called the micropyle, through which the male sperm cells find their way, take possession of the disc, or female germ on the yolk, and impregnation or fertilization takes place. As it is not likely that the sperm cells can impregnate the yolks till they burst the encasing sacs of the ovary and enter the oviduct, and as a firm membrane, probably impervious to impregnation, soon encloses them after entering the oviduct, it is almost certain that impregnation takes place as the yolks leave the ovary, and at the entrance to the oviduct.

The yolk takes about two days to descend the oviduct and to become coated with albumen and shell. It is possible, with a laying hen, that two or three yolks may be in the oviduct at one time, the last one shelled and the others in different stages, of which at least one will be too late to be impregnated. It is probable, therefore, that not more than one or two ova are susceptible to impregnation at one time, because, as before stated, although as many as twenty ova may be attached to the ovary, it is not likely that any of these can be fertilized till they burst their sacs. The question now is, how long does the vital fluid of the male remain active from one copulation, because upon this depends the number of eggs that can be fertilized by

one coition, and the length of time the eggs will come fertile after removal of the male bird. The writer has never found this to extend beyond from five to ten days, or to about three to eight eggs, generally nearer the former figure rather than the latter. In the case of turkeys it is known that one coition impregnates a batch of eggs, or all the eggs laid till the female becomes broody, but this might be accounted for by assuming that the sperm cells of the male turkey retain their vitality and activity in the oviduct longer than the cells of the males of other species. In the rare cases where a whole batch of hen eggs has continued fertile after the removal of the cock, a similar explanation may be offered, that the length of time the sperm cells keep alive and active, ready to vitalize the ova as they mature and leave the ovary, varies greatly with different male birds. Cases we have seen quoted, where the eggs are said to have been fertile after the cock had been removed ten weeks, are of doubtful authenticity.

How soon after mating may eggs be depended upon for incubation is often asked. This time varies very considerably. It is quite possible, and occasionally happens, that an egg laid on the fourth, or even third day after mating is true to type, but generally five or more days must elapse before the eggs can be relied

upon. It must take some time for the sperm cells to traverse the two feet of oviduct to reach the ovary, there further time, possibly several days, may be taken up in awaiting the liberation of an ovum, and then about two days are needed for the descent of the latter from the ovary to its expulsion, all of which, however, under the most favourable circumstances, may occupy, as before stated, not more than three days. If we assume as correct, what has been asserted by several writers as the result of carefully noted experiments, that, *as a rule*, when a hen is in full lay, the eggs true to mating, commence on or about the fifth day after copulation, and end on or about the tenth, or commence with the fourth egg and end with the eighth or ninth, we may infer that the vital fluid lives and retains its activity in the oviduct for about eight or nine days from copulation.

The sperm cells of the male undoubtedly vary greatly in strength, some probably never reach the ovary at all, or at best, only sufficiently so to impregnate one or two eggs, or of such weak vitality as not to live long enough to fertilize an egg. Again, the sperm cells of a second mating may be stronger or weaker than those of a previous one. In the former case, the second sperm cells may kill those at the ovary from a previous mating, causing the eggs to hatch true to the second

mating after the lapse of even three days. On the contrary, the earlier sperm cells, although older, may still be stronger than those of a later mating, causing the eggs to hatch true to a first mating for a very considerable time after the second male bird has been given access to the hens. This supposition may account for its not being safe to rely upon the eggs of a second mating coming true to type till the hen has concluded its batch of eggs, not that there is danger that the latter may have been fertilized *as a batch*, but that the strong sperm cells of a first mating remain in possession, as it were, impregnating the ova as liberated and kill those introduced later. As a rule, however, the eggs will be true to the second mating in five or six days, and are sooner fertilized to *any* mating if the eggs in the process of being laid were sterile.

NUMBER OF HENS TO A COCK.

In deciding the number of hens to be allowed to run with a cock many things must be taken into account, time of the year, the weather, age of fowls both male and female, breed, condition of the birds, and whether confined, or at liberty. Probably the nearer we approach the natural conditions, the more prolific will be the eggs and the more vigorous the chicks. Early in the season, or in cold weather, fewer hens are

advisable. Both male bird and hens are at their best, that is, in their greatest vigour, at from one year to two-and-a-half years old, younger or older birds mated together, producing less vigorous chicks. Fewer hens of the heavier breeds should be mated to a cock than of the lighter. Birds at liberty are more prolific and a larger proportion of hens can be used to one cock than when the birds are confined, and it is hardly necessary to add that a cock in good healthy condition is better than one out of condition. Being in good condition, however, does not mean being fat in which case he is likely to be lazy. Continual exercise is necessary to fertile eggs. A pen at liberty may be yielding good results in strongly vitalized eggs, confine the same birds in a pen, and probably addled eggs, indicating less vigorous fertilization, will gradually increase, followed by clear eggs in increasing numbers. The same thing applies if we change a strong cock for a weaker one, or in any other way make the conditions less favourable. The following table of the number of fowls to be allowed to run with a male bird must be taken as only an approximately rough guide, as so very much depends upon the stamina of the stock. The table assumes that the stock is fully matured and in good condition.

	CONFINED.		AT LIBERTY.	
	Early in season or in cold weather.	Later in season or in mild weather.	Early in season or in cold weather.	Later in season or in mild weather.
Heavy breeds...	3 to 6	4 to 8	5 to 8	7 to 12
Medium	4 to 7	5 to 10	7 to 12	10 to 20
Light	5 to 8	7 to 12	8 to 15	12 to 24

Cockerels with two year old hens, or a cock in his second season with one year pullets give good results. Cocks over three years old are rarely of much use, although they may fertilize the eggs in mild weather. The following are also general rules, to which, however, there are often exceptions :—A cockerel with a few pullets, say three or four, produces a preponderance of cockerels, especially early in the season. An old cock, with pullets, generally produces a majority of pullets. From *any* mating cockerels are more numerous early in season, and pullets later in the season. Eggs of brother and sister hatch out as well as other eggs, but the chicks are generally weak and difficult to rear.

When the cushion feathers on the hens begin to look worn, or the hens walk lame, it is a sign that more hens may be added with advantage, as it often happens, in confined runs, that the male bird over-exerts himself to no purpose, resulting in a great waste of vital energy if his harem is too small. If this waste of energy could be entirely avoided, as it is avoided to a considerable extent where the birds have their liberty on an extensive grass field, one vigorous young cock is

equal to a surprisingly large number of hens, for this reason, probably, that instinct teaches the hen to seek the company of the male bird when his services are needed. All other attentions forced upon her when confined in a limited space are useless, a source of annoyance, and probably harmful, as it is well known that too few hens, say three or four, to a cockerel, often results in unfertile eggs, whereas, if the number of hens be increased to eight or ten, every egg becomes fertilized.

As a cock does not always 'take' equally well to all the hens of his pen, it is, where convenient, a good plan to have two male birds to be used alternately every two or three days, or weekly. Some cocks are also too solicitous about the welfare of their hens to properly feed themselves, with the result that they get out of condition. The poultry keeper should watch for this to ensure that such get properly fed.

CHAPTER XXIV.

OPERATING INCUBATORS.

The ideal place for the operating of an incubator is one having an equable temperature day and night, a moderate and constant degree of humidity, a steady supply of pure air, and freedom from noise or disturbance of any sort. An underground cellar best fulfils these conditions. The temperature of such a place does not fall as low during the night, or rise as high, or fluctuate as much during the day as one above ground, and as its temperature is more uniform, its humidity is also more constant. The cellar, however, must not be damp, dark, or badly ventilated, as, in the latter case, the accumulation of carbonic acid, and other injurious gases, is likely to be excessive, and the supply of oxygen correspondingly deficient. No better criterion of suitability can be had than the sense of smell. If the room smells unwholesome, disagreeable, and not fit for human occupation, it is equally unfit for the successful incubation of chicks.

THE EGGS FOR SETTING.

The first and most important question is the eggs themselves. Sufficient consideration is not always

given to the quality as distinct from the mere fertility of the eggs. The germs vary greatly in strength and vitality, and there are many things which must be guarded against, if well-vitalised eggs and vigorous embryos are desired.

The breeding of stock must be fully matured, strong, and healthy, and the sexes unrelated ; and experience points to the fact that, in mating, the sexes should not be of the same age. As a rule, best results are got from two-year-old hens and a year-old cockerel. As so much depends on the cock, he should be carefully watched, especially on coming out in the morning, and after the evening meal, to see if he is active, as the hatches of a whole season may be spoiled by failure in this quarter.

It is often noticed that cross-bred eggs hatch out better than those of pure-bred birds, the constitutions of the latter having been, no doubt to some extent, enfeebled by too close a relationship in the parents, and by the necessary in-breeding that has been resorted to, to maintain the purity and external characteristics of the type. This consideration, however, is not an important one if the birds are kept under healthy conditions.

Moreover, the breeders must not be over-forced or stimulated, the effect of which obviously is the straining of the egg organs, resulting in the impoverishment in the quality, or the production of "watery" eggs. It is evident that any depreciation in the richness of the materials to form bone, feather, and tissue will weaken the chick and diminish its chances of successful hatching. The liberal feeding to the stock birds of nitrogenous or animal food in any form will largely overcome this.

It has often been noticed that, during the strain of a term of continuous laying, the eggs become less and less strongly vitalised, till they will not, though fertile, even hatch out, much less produce vigorous chicks. When this is the case, the introduction of a fresh cock, preferably one that has not been much used, may overcome this failing, as the fault is more probably in him than in the hens. For this reason, it is not wise to mate up the breeding pens longer than about a fortnight before the eggs are required for setting, as the vivility of the male, as well as the fecundity of the females, become gradually impaired the longer the same birds are together. When there is difficulty in getting the eggs fertilised, it is recommended, as a good plan, to allow the male bird to run with the hens early in the morning and in the evening

only, removing him after the first meal till the last meal of the day. An occasional serving of hemp-seed is also good for the same purpose. If a faithful sitter, under favourable conditions, cannot hatch out 90 per cent., it is probable the eggs are weakly fertilised, as a really vigorous germ will bear an almost incredible amount of ill-usage before it is killed outright.

SELECTING EGGS FOR SETTING.

Set only fresh eggs, the fresher the better. When eggs are kept some time before being placed under the hen, the membrane lining the shell becomes very dry making it, when the time arrives for the chick's exit from the shell, too tough for the inmate to break through, and the fully developed chicken dies of suffocation unless helped out. If the poultry-keeper has some valuable eggs that have unavoidably got old before being "set," soaking them in warm water for from a quarter of an hour to an hour, according to the degree of their staleness, will to some extent, remedy the dryness of the lining membrane, and improve their chances of producing chickens.

Select only eggs of good shape and of medium size, discarding very large and very small eggs, and those with crinkled or rough shells.

The eggs should be clean. It must not be forgotten that the embryo in the shell requires air from the first day of its incubation, and if the pores of the shell are filled with dirt, death is sure to ensue. Hence the necessity, when the eggs have become smeared by an egg getting broken in the nest, of washing the remaining eggs with warm water, as the dried albumen and yolk would as effectively seal the pores as a varnish. The writer has coated with different substances incubator eggs in various stages of incubation, and the inmates invariably died within thirty-six hours of their exclusion from a supply of air from the outside.

THE BEST TEMPERATURE.

The heat under a hen varies from 105 degrees in the centre to 101 or 102 degrees near the outside of the nest. The best average temperature to operate an incubator is, as near as possible, between 103 and 104 degrees, or slightly higher in cold weather, and lower, if any deviation is made, in very warm weather. If the heat is too high, the chicks will hatch out on the 19th or 20th day ; and, if too low, on the 22nd day. In neither case, however, are the chicks, as a rule, as vigorous as when hatched in a normal manner on the 21st day. The bulb of the thermometer should rest on a fertile egg, or, at least, not on an

infertile one, there being a difference of several degrees in the registering between a dead egg and one just ready for hatching, and a considerable variation between the readings of a thermometer placed on a fertile egg, and an inch or more above it. In practice, when not convenient to distinguish between live and dead eggs, let the bulb of the thermometer be placed about one-eighth, or one quarter of an inch above the eggs.

COLD EGGS IN INCUBATOR.

The greatest measure of success cannot be attained in any machine when the eggs are placed in at different times. Even after the last eggs have become thoroughly warmed through, they will always remain a degree or two below those in a more advanced stage of incubation, owing to the gradually increasing generation of animal heat in the latter. If, therefore, the bulb of the thermometer is placed on one of the older eggs, and the incubator adjusted to work to its reading, say 104 degrees, the eggs placed in the machine last would be underheated, a thermometer placed on one of them registering probably from 102 to 103 degrees. If, on the contrary, the heat of the chamber were raised to keep the reading of the ther-

mometer on a new egg at 104 degrees, the older eggs would be at from 105 to 106 degrees.

If the operator is very wishful to place eggs in the incubator in batches, they should be separated by a partition of cardboard or wood ; and, by placing thermometers on both lots of eggs, the incubator should be so adjusted to work as to keep the mean of the two readings as near as possible $103\frac{1}{2}$ degrees.

TURNING THE EGGS.

The hen, on returning to her nest almost invariably shuffles the eggs, apparently in an aimless manner. The eggs in an incubator should be turned twice a day, not, as is sometimes supposed to warm them all round. During the earlier stages of incubation, the embryo, which is attached to and floats on the top of the yolk, presses upward against the inside of the shell, and, if allowed to remain long in one position, the albumen, being rendered more fluid by the continued high heat, is gradually forced aside, the heat dries the thinned stratum of albumen left, and the germ becomes glued to the shell.

Moreover, the germ, in the early stages, gets oxygen directly from the white, and a change in the position of the egg, by the rotation of the yolk, brings a fresh portion of albumen in contact with it.

Again, if the egg is not turned regularly the white has a tendency to separate into its constituent parts, the water sinking to the lowest part of the egg. When the blood vessels, in their search for air and nourishment, come in contact with this watery portion, further progress is arrested, just as the roots of a plant are stopped and distorted by a stone. As all the vessels break off at the same level, a red line (like a thumb mark) is formed near the shell, lengthwise with the egg, marking the place of obstruction. As it is necessary for the chick that the blood vessels should evenly, and completely, cover the shell of the egg, in order to absorb a sufficient supply of oxygen from the air, and of bone-making material from the shell, anything which prevents this will, probably, kill the chick, or cause it to grow crippled in shape or so distorted from its natural position as to render its exit impossible.

In turning the eggs care should be taken to have the large end, or widest part slightly the highest during the first seven or eight days. The tendency of the embryo seems to be to grow with its head in the highest part. The natural shape of the egg and the position of the air cell, however, is such that it generally keeps itself right in this respect, especially in the natural nest, where the small end will nearly

always be found turned towards the centre or lowest part ; but, if by chance, the small end should be propped up the highest for the first week, it is probable that the head would be formed in that end, and this not being the normal position, such chicks are rarely able to get out. By the sixth or seventh day the blood vessels have begun to attach themselves to the shell, and about the fourteenth day the chick moves from crosswise, the position it has occupied till this time, to lengthwise of the egg ; but if its head, on the seventh or eighth day, be turned too much towards the small end, it will never sufficiently reverse to get itself into the proper position for coming out easily.

CHANGING THE LOCATION OF THE EGGS.

Not only should the eggs be turned over, but their position in the incubator should also be changed, or the tray or drawer reversed, where the construction of the machine permits it. It is practically impossible to construct an egg chamber, except one of small area, which will maintain an equal temperature in all parts. Therefore, by changing the location of the eggs twice a day, the ill effects of a continuous temperature a degree or two too high or too low, will be obviated.

COOLING AND AIRING.

When the eggs are turned, they are better allowed to cool once a day for five or ten minutes in the summer during the second and third weeks of incubation. During the first week they need no cooling, and in winter they are as well without it even during the second and third weeks, unless it can be done without allowing the eggs to fall in temperature below about 75 or 80 degrees.

The hen allows her eggs to cool, but on her return they are warmed up at once. When cooling incubator eggs is thought advisable, the machine should be closed to keep in the heat, while the eggs are out, otherwise they may be too long in getting up again to the required temperature. Never allow either the eggs or the incubator to become so cold that the heat cannot be got up again within the hour. Eggs in process of incubation that have been accidentally allowed to get very cold or chilled by long exposure, may, with advantage, be placed for fifteen minutes or longer in water at 105 degrees. Keep a thermometer in the water to register the heat, and add warm water from time to time as needed. Dry the eggs before putting them back.

CARE AT HATCHING.

After the 18th day do not turn the eggs. The chicks are then, or should be, fully formed, and a majority of them will naturally get into position, with beaks up, ready for coming out, but if turned on the 19th or 20th day, probably more will chip the egg on the under surface than would otherwise be the case. Many, however, will, under any circumstances, chip the under side first ; and, although it is an unwise proceeding to open the incubator, especially at this time, oftener than is absolutely necessary, the chipped side should be turned up by opening the machine every half-dozen hours or so, closing it again as quickly as possible.

It is advisable to turn the chipped side up for these reasons :—A chick may fracture the shell close against the bottom of the egg tray and be unable, owing to this, to make a hole sufficiently large to admit air to breathe, and, as a consequence, may suffocate. Some eggs, also at hatching, contain a quantity of refuse watery or gluey matter, which is liable to close up, and sometimes glue up, the hole when it happens to be in the lowest part of the egg.

When hatching, keep the incubator at 103 or 104 degrees. Do not let the heat exceed 104. At this

time the struggles of the chick generate several degrees of heat.

Chicks, as a rule, will come out in from six to twelve hours after chipping, depending upon their strength and the thickness of the shell and lining membrane of different eggs. Before its exclusion it should have absorbed into its abdomen all the remaining unconsumed yolk, which constitutes its food for the first twelve to twenty-four hours.

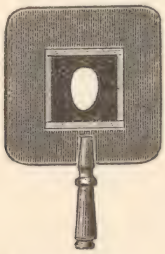
In large incubators chicks can never be expected to all hatch out on the same day, till it is possible to get all the eggs of equal age, the germ of uniform vitality, and the conditions of heat, moisture, ventilation, etc., uniform in every part of the incubator.

EGG TESTING.

Where many hens are set, or an incubator is used, it is advisable to test the eggs about the seventh day in order that the infertile and those in which development has been arrested may be removed. It is useless wasting the time of either hens or incubators upon eggs which cannot hatch chickens under any circumstances. Where many eggs are incubated the great saving of eggs, which are still good for culinary

purposes or as food for young chickens, and of incubator space, either artificial or natural, by the removal of the infertile eggs, fully repays the poultry keeper for the trouble and time involved in examining the eggs, as a mere glance is sufficient to decide whether an egg is good or not.

DIFFERENT METHODS OF EGG TESTING.



EGG TESTER

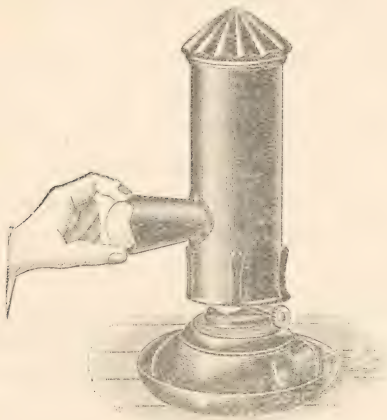
The object in egg testing is to get a strong beam of light to pass through the egg. Cut a hole about the size and shape of an egg in a large piece of cardboard. Hold the egg in front of this hole before a strong light ; no other light should be in the room. Or, a cylinder of cardboard, or other suitable material, might be made of a diameter wide enough to close the lamp, or, at least, the lamp flue. Immediately opposite the flame cut a hole as described above. The

whiter and brighter the inside of the cylinder the better, as the reflected light will intensify the rays passing through the egg.

The hands alone are even sufficient for egg testing purposes, with a fairly good light, provided that the walls of the room are dark, and that there is, in consequence, little reflected or distributed light. Hold the egg between the finger and thumb of the right hand, then place the left hand also close to the egg in such a way that the palms of the two hands form a rough concave reflector turned towards the light.

To test in the day time a dark room with a single aperture to admit daylight provides an excellent method, and no more powerful light could possibly be had than bright sunlight admitted through a hole into an otherwise totally dark room.

There are many egg testers on the market, and most incubator makers send out one with their machines ; but the best the writer has seen consists of a lamp with a special metal chimney, the polished inside of which acts as a reflector. In this chimney, and at right angles to it, a second tube is fixed directly opposite the flame, in which is fixed a plano-convex glass lens, which concentrates a powerful beam of light on the egg.



DAWSON'S PATENT EGG TESTER.

By means of a very strong light, such as that of bright sunlight, it is just possible to discern the location of the germ after thirty-six hours of incubation, but for all practical purposes the fifth, sixth, or seventh day is as early, with ordinary methods of testing, as it is possible to decide the conditions of the eggs with certainty. If examined earlier there will be so many doubtful ones, which must be put back into the nest, as to necessitate another testing a day or two later, rendering thereby the first examination a mere waste of time.

APPEARANCE OF FERTILE EGGS DURING DEVELOPMENT.

In an egg that is progressing satisfactorily there may be seen about the fourth day, on examination, a small circular spot, near the thick end of the egg, about the size of a threepenny piece, a little less transparent than the remainder of the egg. This germ membrane gradually darkens, the vessels to and from the germ become numerous, and by the sixth or seventh day the embryo appears as a dark spot in the centre of a number of bright red veins, or in other words, something like a spider with long legs. The better to see this, it is advisable, when lifting the egg from the incubator or nest to examine, to keep the side uppermost in the drawer towards you, as the embryo, floating on the top, can thus more readily be seen.

The germ should, at this stage, be quite free from the shell, so as to move about a little when the egg is turned in the fingers. If it does not move when the egg is gently shaken, it has become fast to the shell owing to its not having been turned sufficiently often, or to excessive heat in incubator. When the egg is turned over it may free itself and rise to the opposite side of the egg, as the germ, if not stuck, always floats on the top. If it does not do this death is sure to ensue.

The germ presses upwards against the shell, and if by accident the heat in an incubator has been allowed to rise excessively, the thinned stratum between the germ and the shell dries and glues the embryo to the shell. When this mischance happens, the best thing to do is to turn all the eggs over at once, when the yolk and the germ with it, owing to its lesser density than the white, will, if not already too securely fastened to the shell, rise to the opposite side and thereby free itself. It is not the few degrees of extra heat which kills the embryo directly. The latter dies afterwards through derangement of its functions as a result of this adhesion.

The egg gradually becomes more and more opaque, the opacity being first on one side only, the other side and small end being transparent, till by the sixteenth or seventeenth day the egg appears quite dark in every part except the air cell, which, as incubation has advanced, has been growing larger, till, on the nineteenth or twentieth day it occupies about one-fifth or one-sixth of the interior. Just before hatching the chick works itself up till it fills the whole space.

APPEARANCE OF INFERTILE AND ADDLED EGGS.

So far we have described the appearance of an egg developing. Infertile eggs, that is those which have

not been vitalised, will be found, when examined about the seventh day, to be quite clear like fresh eggs. Fertile eggs in which the yolks have been broken, and in which incubation has advanced one or two days, appear turbid, that is, not so transparent as an infertile one, nor in any part so dark as an egg in which the embryo is alive. They have often also, especially if the germ has lived a few days, a distinct blood line, like a thumb mark, near the side of the egg.

Dead germs on the seventh day present varied appearances, in all of which, however, the spider-like blood-vessels have disappeared. Addled eggs, or those in which putrefaction has set in, have one or more dark looking masses, portions of which may adhere to the shell. In such eggs, by the tenth or twelfth day, the dark-looking mass or masses float about, when the egg is turned in the fingers, as the blood vessels, which, by adhering to the shell, steady the living embryo in the egg, are dead.

THE WATER TEST.

On the twentieth day the eggs which contain live and fully-developed chicks may be ascertained by the warm water test. This method, however it may satisfy curiosity, often does harm to the inmate of the egg, so chilling many that they fail to hatch out,

To minimise this risk of injury, the eggs, after being removed from the water, should be dried and placed under the hen or in the incubator immediately.

Eggs containing live chicks, if immersed in water heated to about 105 degrees, that is, about as warm as the hand can very comfortably bear, after a minute or two will begin to jump about in a lively fashion, stimulated by the warmth of the water. The eggs containing dead chicks will sink, though it is just possible that a chick after it has worked itself up to fill the interior of the shell, as it does before its exit, may, by filling up the air space, so destroy the buoyancy of the egg as to sink it. The writer has never found an egg containing a live chick to sink, but it is asserted by some that such cases occasionally occur.

The eggs which do not either sink or jump about in the water contain (if seen to be fully developed on testing with a light) chicks which are either not ready for leaving the shell or have only recently died. These should be replaced in the nest, or subjected to a further test. If on shaking the egg the contents rattle, the inmate, of course, is dead and shrunk in the shell; or if, on examination with a light, there is the slightest transparency anywhere, except through the air cell, the egg may be thrown away as worthless.

HELPING OUT.

On the twenty-first day, if there are still any doubtful eggs, a small hole may be made in the thick end of the egg and a drop of water allowed to fall on the membrane (which will be white if the chick is alive or has recently died) in the air cell. This will render the membrane transparent, and if the blood in the blood-vessels is visible, the chick is alive and may possibly need helping out.

In doing this proceed very cautiously, and do no more than help the chick to help itself by freeing it a little. If blood comes it is a sign that the contents of the veins in the lining membrane have not yet been absorbed into the body, and the chick is not ready for coming out.

Helping out may be safely resorted to when an egg has been chipped twelve hours and does not appear to be making headway.

CHAPTER XXVII.

HATCHING DUCKLINGS.

The following extract is taken from "Duck Farming, or, How to Breed and Rear Ducks with success in Confinement, without Bathing Water," by the author of this book.

"Whether with hens or incubator (ducks themselves being only indifferent sitters and wretched mothers) duck and hen eggs may be hatched together, but they do better separately. The former will hardly keep as long for incubation purposes as the latter, for the reason probably that they are more porous. If hatched in incubators, they require a slightly lower emperature than hen eggs—namely, about 103 degrees, or lower rather than higher, hen eggs doing best at from 103 to 104. They also need more moisture as hatching time approaches, but not before.

"The accompanying drawing shows the size of the air cell of a duck egg as seen through an egg tester, at different stages during its incubation. If, on examining a batch of duck eggs in an incubator, the air vesicle is smaller on the respective days than as shown in the diagram, it is probable that either the machine

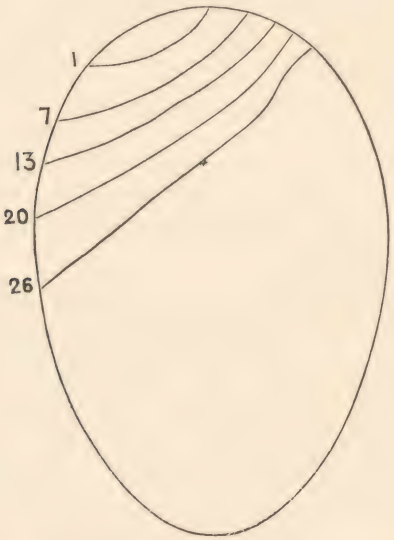


DIAGRAM SHOWING SIZE OF AIR CELL OF DUCK EGG ON THE ABOVE DAYS.

has too little ventilation, thereby checking the drying down of the egg sufficiently, or the eggs are receiving too much artificial moisture, which has the like effect of preventing the necessary amount of evaporation of moisture from the egg. Therefore, to enlarge the air cell, increase the ventilation, or, in other words, allow rather more fresh air to pass through the incubator,

and use less water. If the air vesicle is found already too large, retard development or the drying down of the egg, by lessening the amount of fresh air passing through the machine, or increase the amount of moisture.

"As ducks are water fowl, some people have the impression that they cannot be kept too moist during incubation, advising a damp location to be selected for the nest, and a daily sprinkling of the eggs to correspond with the damping the eggs would probably receive from the feathers of a duck, incubating naturally, after its daily swim in the water. The eggs under a hen or duck become coated with an oily secretion or perspiration from the body of the sitter, rendering them much less affected by the humidity of the outside air, but in an incubator the eggs have not this oily protection. They are very porous, the effect of too much moisture throughout the whole month of incubation being to prevent the ducklings being sufficiently dried down, and so occupying too much space in the shell at the time of hatching. They chip the shell, and get the bill well out, but owing to the former being so densely packed, the duck has little or no room to stir. It cannot get its bill back through pressure from the inside, neither can it turn round, to cut off with its bill the upper part of the

shell, and, consequently, it dies from sheer suffocation or exhaustion unless helped out. During the last week, however, the case is different. The duck should be, by that time, well dried down, then, by plenty of moisture and a daily fine spraying (after which the machine must be immediately closed to prevent chilling the eggs), the shell and membrane must be softened and prepared for the duck's exit.

"Should the lining membrane, at hatching time, still be rather tough, as is often the case, some of the inmates may need helping out of the shell, especially if chipped at the small end or near the middle. This may be done with less risk than with chicks. Of the latter, those which cannot get out unassisted, are rarely worth the labour involved in helping them, but ducks needing this assistance, if given at the right time and a little at once, are afterwards usually as strong as any others.

"Ducks generally chip the shell from 12 to 36 hours before making their exit, during which time they are absorbing the remaining yolk for their support immediately after hatching. When necessary to open the incubator, say every eight or ten hours, the chipped portions should be turned upwards, and the fracture examined to see if the membrane is broken. If not, make a small hole to admit air, and if after-

wards the duck does not make satisfactory progress, take the top of the shell off, if this can be done without causing bleeding.

CHAPTER XXVIII.

THE REARING OF CHICKENS.

Success in raising chicks artificially depends as much upon good brooding accommodation as upon the hatching, as the most profitable chicks for table purposes are brought into the world at a time when the severest winter weather must be prepared for. It is also easier, as well as far more profitable, to rear hundreds of chicks with suitable foster-mothers than dozens by the natural method.

In a good foster mother the chief heat should be from the top. In brooding, the hen sits on the ground, the chicks nestle amongst her feathers and are surrounded by a genial warmth. Even the ground is heated considerably by the heat from the fowl's body. In the artificial mother, if all the heat is in the top, the chickens clamber for the uppermost

place, and the weaker ones get crushed to death. Chicks sit down to sleep, and a cold, and especially damp floor, however warm it is above the chicks, chills them, or causes cramp or crowding. The position of the source of heat is of much less importance than its even distribution.

HEAT AT WHICH TO WORK A FOSTER MOTHER.

If the chicks hatch out on the twentieth day, the probability is the incubator has been operated at too high a heat. If, on the contrary, the chicks do not come out of the shells till the twenty-second day or hatch out weak, there has been either too low a heat, or the eggs were stale, or from immature, debilitated, or overfed stock, and, as a consequence, lacking in vitality. The chicks should be allowed to remain in the incubator, unless a warm drying box is provided for ten or twelve hours after they are hatched, that is until they are thoroughly dried, and have assumed their fluffy or downy appearance. For the first twenty-four to thirty-six hours warmth is all the chicks need. They are at this time, as it were, almost naked, as their downy covering is not a very good protection against cold, and if a chick once becomes chilled and stunted, it never fully recovers, and is never able to regain lost time. At first the tempera-

ture in the brooder should be from 90 to 95, gradually lowering it to 70 or 75 by the end of the third or fourth week. Too much heat is as great a mistake as too little. Chicks, when a week or ten days old, can bear a considerable amount of cold without harm, if the weather is dry and they always have at hand a warm snug brooder to run to. If the chicks are watched in cold weather, it will be noticed that they do not remain out long at a time, but frequently return to the foster-mother to get warmed up again. No thermometer need be used to ascertain the best temperature at which to keep the brooder, as the best criterion of this is the chicks themselves. If they chirp about discontentedly or huddle together, or have a hardness about the vent, indicating diarrhœa, the probability is more heat is needed. It should not be forgotten that the hen broods her chicks with, approximately, the same temperature with which she hatches them.

Chicks crowd and trample each other only when they are cold and uncomfortable. Give them sufficient heat and they will squat contentedly in any part of the brooder floor. Although ample warmth is necessary, coddling in any form defeats its own purpose. Artificial heat should be supplied for from three to six weeks according to the weather, continu-

ing it at night after it has been discontinued during the day.

CLEANLINESS.

Cleanliness is of the greatest importance. Without it disease, death, and failure are certain. Leave no stale food about, remove the excrements, and clean the feeding troughs and the floor of the brooder frequently. This entails some trouble, but it is necessary to success. Incubator-hatched chicks start life free from the insect pests, which sap the life-blood of naturally-hatched chickens, and if kept away from hens will not be troubled with them, and, as a consequence, they will not be liable to many of the ailments of chickens brooded by the hen. If, however, insects should attack them, on the first indication as shown by drowsiness, discontented chirping, ceasing to thrive, roughness of feathers, etc., examine the heads and under the wings for lice. Use lime wash, to which a little glue has been added, frequently.

DAMPNESS.

Chickens can bear cold after they are a week or two old, but dampness is fatal to success at any stage of the chick's career. The floor of the foster-mother should be covered with sand, dry earth, moss litter, or chaff, etc., as bare boards cause leg weakness, and

even covering a stone or boarded floor to the thickness of one or two inches with the above will not altogether obviate the danger, if it is attempted to rear them altogether on such a floor. They must have a run on the bare earth (in bad weather the run must be covered), as chicks cannot be reared inside altogether on any kind of floor.

NUMBER IN ONE FLOCK.

The number of chicks that may be allowed together depends greatly upon circumstances. Like fowls, they do better, as a rule, in small flocks ; but it is as safe to keep 50 or even 75 together under some conditions as 20 or 30 under others. The conditions are plenty of room, a fairly equable temperature in all parts of rearer, no corners, the chicks all of one age, with the removal of the weakly ones.

GRASS OR SOIL.

It is immaterial whether the foster-mother and run are placed on grass or soil. Both have their advantages, though short grass is often preferred. Dry soil or sand supplies much food that grass fails to supply, provides better scratching exercise, and can be kept sweet longer by being dug or hoed over. This is an important consideration where space is limited, as grass runs need to be changed daily.

FEEDING CHICKENS.

For the first twenty-four hours at least, the chicks do not require feeding, the yolk absorbed at hatching time supplying all the nourishment needed during that time. After the first day, feed every two or three hours for the first week, gradually lessening the number of meals a day to three by the time the chicks are a month old. The first and last meals should always be as early and as late as possible, in winter it being necessary to give these two meals by lamp-light.

For the first day or two feed the chicks on any of the following :—

(1) Hard boiled egg (the infertile ones removed from the incubator will do very well for this purpose), chopped fine, shells included, and mixed with an equal quantity of stale bread crumbs, the whole moistened with milk into a friable condition.

(2) Coarse dry oatmeal.

(3) Stale bread alone, or moistened with milk or water, may also be given.

After the first few days any of the following foods may be given, the more they are varied the better :

(4) Coarse oatmeal dry, or moistened with milk.

(5) One-third oatmeal to two-thirds barley meal, scalded with boiling water, and mixed into a crumbly condition,

(6) Five parts oatmeal to one of boiled rice, mixed as the last.

(7) Boiled rice mixed into a friable state with meal. This is a specially good food for checking diarrhœa.

Accustom the chicks early to crushed wheat, afterwards giving them the grain whole. Bran is very indigestible, and irritates the bowels unless well scalded to soften it, then it forms an excellent bone-forming food. Animal food, chopped very fine, should be given in moderation from the first week. If the chicks are not provided with a grass run, green food must be supplied without stint. Onion tops, cabbage, lettuce, and nettle leaves are specially good.

Chicks do not eat much at a meal, but they eat often. Give them regularly as much as they will eat, then take up the remainder till the next meal. It is a good plan to keep a box of ground bone always accessible to the chicks. Sharp grit or sand should be scattered on the food, and a dry dust box should be provided. Lime water added to the drinking water is beneficial. If there are any signs of leg weakness

from rapid growth, put a teaspoonful of citrate of iron and ammonia in each quart of drinking water, or a few rusty nails even will answer the same purpose. The state of the droppings is a good test of health. When they are of a brownish colour, capped with white, the chickens are thriving.

For fuller information on this subject the reader is referred to "Profitable Poultry Farming," *(L. Upcott Gill, London), by the author of this book.

CHAPTER XXIX.

GREEN BONE AS A POULTRY FOOD.

The value of cut raw bone as an egg producer cannot be too widely known. It contains the elements required in the complete egg in almost identical proportions, and in an easily digestible form.

In 100 parts of egg, including shell, the constituents are about in the following proportions—viz, 64 water, 15 dry albumen, 11 oil and salts, 10 shell and mineral matter; or, in the white and yolk together, without

*Price 1/2, from the Author, Fellscliffe, Ripley, Yorks.

shell, there are in 1 lb. of eggs about 2 ozs. of proteids (flesh or muscle forming elements), $1\frac{1}{2}$ ozs. carbon (heat and fat producing), $\frac{1}{4}$ oz. minerals, and $12\frac{1}{4}$ ozs. of water. The composition of butcher's meat varies greatly according to the amount of fat, bone, etc., included; but the elements in lean meat (beef, mutton, etc., not cut raw bone, although for practical purposes the following analysis will apply, with some modification, to raw bone with the flesh, etc., adhering) may be roughly taken as follow:—In 1 lb. of meat there are about 3 ozs. of proteids, $1\frac{1}{4}$ ozs. carbon, $\frac{1}{4}$ oz. of minerals (phosphates, salts, etc.), and $11\frac{1}{2}$ ozs. of water.

Grain alone does not contain the necessary materials in proper proportions. Fowls may be kept in good health on grain, but with a grain diet solely, the proportion of carbonaceous elements (starch, fat, etc, heat and fat producing, and for supplying the elements of respiration) is too large, causing the surplus to be stored up as fat, and fat hens never lay well. To make the matter clearer, experience teaches that to feed properly, the proportion of nitrogenized elements (proteids = flesh formers and egg producers) to non-nitrogenized elements (starch, fat, etc.) should be about as 1 : $3\frac{1}{2}$ or 4 in warm weather, and as 1 : 4 or 5 in cold weather, and this ratio must not be disturbed.

Thus, if the proportion required is, as above, as 1 : 4, and 1 : 7 or 1 : 8 is given, as is approximately the case when grain only is given, the 3 or 4 parts extra of non-nitrogenized elements are passed through the system and wasted, or are stored up in the system in superfluous fat. The "albuminoid ratio" (that is, the ratio the albuminoids, or nitrogenized elements bear to the carbonaceous or non-nitrogenized) of some of the more generally used grains is as follow :— Wheat, 1 : 6·5 ; oats, 1 : 5·9 ; barley, 1 : 8 ; maize, 1 : 9·9 ; buckwheat, 1 : 4·75 ; whereas, the ratio for eggs is as 1 : 1·9, and of lean meat when the constituents are as given above, as 1 : ·417. The above grains, as egg producers, may be placed in the following order :—Buckwheat, oats, wheat, barley, maize ; but all of them require, for egg production, the addition of more or less of animal food, to further reduce the proportion to as 1 : 4. The lean meat, fat, marrow and gristle of raw bone contain just the elements necessary to form the white and yolk, and the bone yields the necessary lime salts for the shell.

The hen may be looked upon as an egg-producing machine, but she must have the raw material from which to manufacture her products. Place within her reach all she requires for her work, and instinct will teach her which to select. The omission, how-

ever, of any one essential in the composition of the egg, though everything else be supplied in abundance, will interfere with egg production, if it does not stop it altogether.

During the winter, fowls may be well-fed, sheltered and cared for, but if the food given does not contain the elements necessary to produce eggs, the latter will always be scarce. In summer, insects, worms and animal food, rich in albumen, the chief egg-forming material, are abundant; but on the approach of winter, this supply fails, and with it the supply of eggs. All fowls in winter, and nearly all in summer, must have this egg forming animal food artificially supplied, and probably the most perfect food for this purpose is fresh green or raw bone.

Dry bone meal, furnishing material for shell and bone only, is no substitute for green bone. There is a very wide difference in their nutritive values. Green bone, being a food as much as wheat or oats, can be fed largely with excellent results, whereas only a very limited amount of ground dry bone is of any use in the bird's system.

None of the prepared, patent, so-called animal foods supposed to take the place of insects, etc., are equal in nutritive value to green bone. If the feeding of these

foods is beneficial to the fowls, much more so will be the feeding of fresh cut meat and bone, rich in every element, and containing all the essentials for the formation of eggs, flesh, muscle and bone.

Condiments, and so-called "egg foods." are simply stimulants, and, although of some use when judiciously used, they do not provide materials from which to make eggs.

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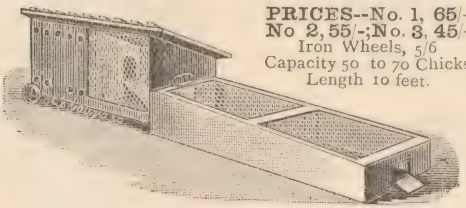

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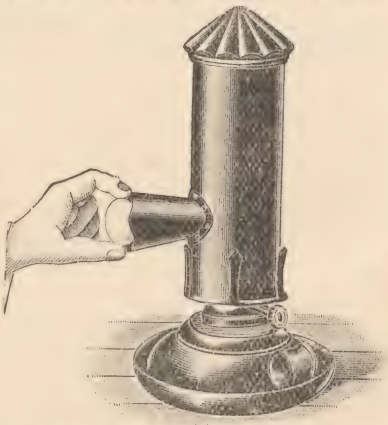

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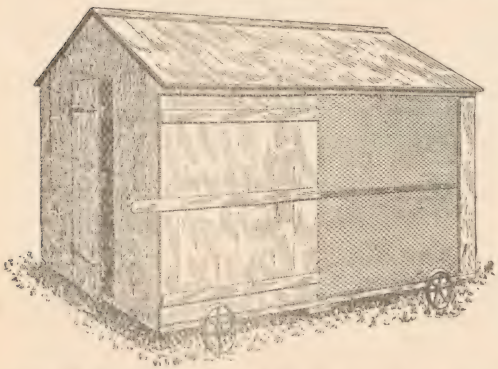

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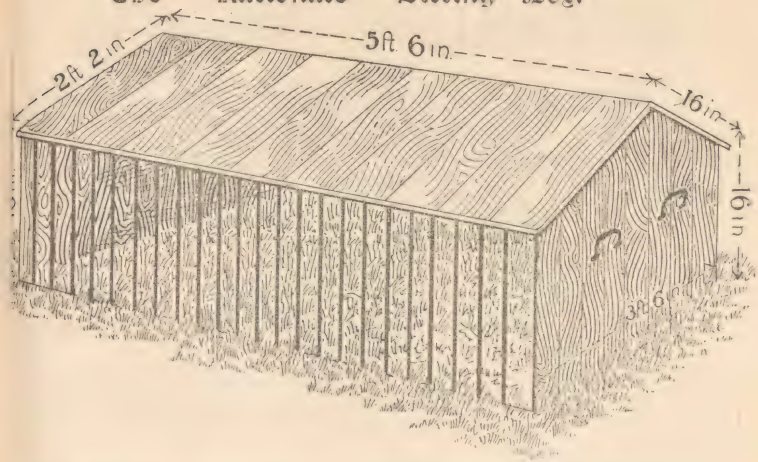

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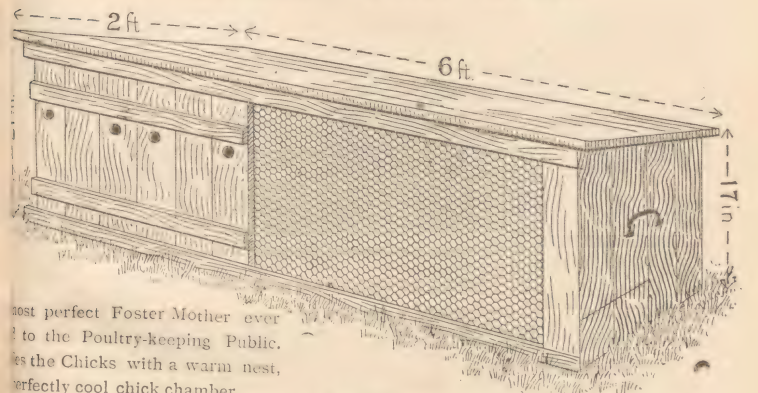

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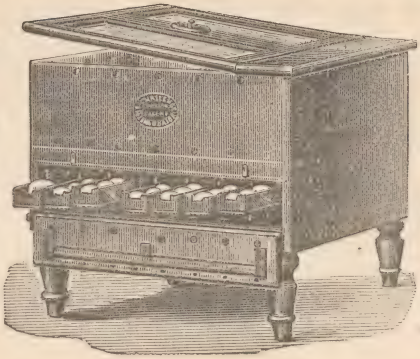

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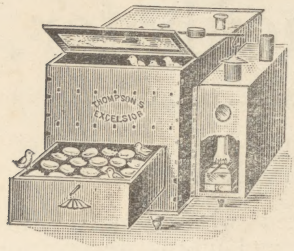

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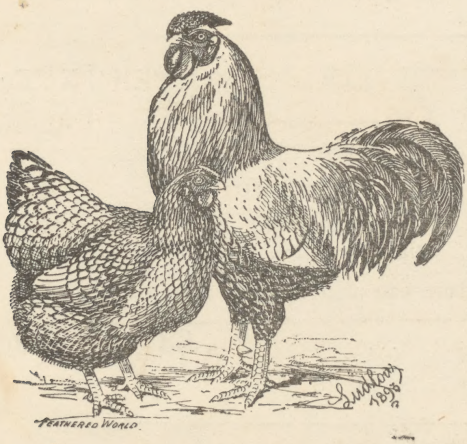

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